Gene-Hull 2.3_User Guide_English version

This **upgrade 2,3** for VE and UE versions of the application includes the following improvements :

- **one can input the X longitudinal position of the hull max draft** : it is the input data « X Tc »
- **one can introduce a scow bow influence** on the front sheer line and waterlines : it is the input coefficient « Scow »
- **one can introduce a hard chine**, above the waterline and vertical, leaned on 2 or 3 points (detailed further in the User guide)
- **an early stage Sailplan can be defined** (input : mast position , I J P E values), from which the « lead » is computed (>>> the optimal relative position of the mast and the keel wing) and also the ratios involving the sail surface.
- **an early stage Mass spreadsheet can be defined**, from which the light boat weight and CdG coordinates are computed
- **the hull with heel hydrostatic equilibrium (height, trim) can now be based on the hull mass and CdG position, and the RM can be computed for each heel angle.**

Gene-Hull makes possible the **generation of hulls for sailing yacht** with their 2D views and their hydrostatic characteristics as output, keel and rudder included. It is based on a spreadsheet application (Open Office Calc 4.0.1) involving fit for purpose formulations of the polynomial type, able to generate the hull fairing lines. It needs a relatively small number of data to enter : basic geometrical data, parameters used in the formulations. This User Guide gives all definition and information on the role and influence of each data, with illustrations. Moreover, the User has the input data of a reference hull allowing him to start his own project step by step, and a « Hulls storage » sheet where other examples of inputs are archived and can be copy/paste.

For each new data introduced, all the computations and the drawings are updated automatically. Proposed parameters allow an infinity of combinations, so as many possible variants of a hull. Drawings and hydrostatic data, including ratios usually considered by naval architects, make possible to judge the hull and to converge towards the desired one. In section 6. of the results, the computation of the hull-keel-rudder with heel angle is also proposed, in hydrostatic condition, at iso displacement and with control of the longitudinal center of buoyancy thanks to iteration on height and trim parameters. It provides the transversal offset of the center of buoyancy and so the corresponding contribution to the righting moment, and 2D drawings (sections and floatation waterline) which can help assess the relevance of the hull with heel.

Produced data allow either to continue the project with a 3D modeller (for that option, all necessary data are provided in section 5.) or, for amateurs in particular, to draw at scale one any sections and frames needed for a building (data are provided in section 7.).

Two similar files « VE » and « UE » are proposed, one **VE** involve sections defined by combination of « V » and « E » shapes (E for Elliptic), the other one **UE** involve sections defined by combination of « U » and « E » shapes. A specific « VE double ended » file and its user guide are also available on request for that kind of hull with a double ended configuration.

In the present state of this development, some limitations exist which could be overtaken within further versions already in preparation. Main is :

- necessarily inverted rear transom (but hull with classic transom can be generated, it is just that the transom itself is not drawn)

After an apprenticeship that should be light thanks to this User Guide and the hull of reference given to initiate a new project, it is easy and even fun to create a great number of hulls within just few clicks, up to test unusual values of parameters to find out new style or shape of hulls : combinations are infinites and sometimes unpredictables (it is also a way to test the limits of this software). Of course at the end, the final choice is up to the User, taking into account his experience as naval architect.

It is a free and open source speadsheet application, on a support itself free and widespread (Open Office Calc 4.0.1) : if any problem are faced to open and use an ods file, you can download Open Office or Libre office according to : http://www.openthefile.net/extension/ods

On request, a technical appendix can give you all the formulations involved and if necessary you can improve the tool yourself and share it with the community of amateurs of naval architecture. Or you can contact me with your remarks and improvement requests.

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Summary presentation

The application includes 4 sheets :

- Gene-Hull
- Hulls storage
- Sailplan
- Mass spreadsheet

Gene-Hull : includes an User space (input & outputs) followed by an Administrator space where the computations are carried out. The User space includes 7 successive sections :

Gene-Hull input :

1. Data to enter

Gene-Hull output :

2. Data sum-up and results of hydrostatic and surfaces calculations
3. The 3 views 2D
4. Curves of control
5. Data for transfer to a 3D modeller
6. Hull with heel
7. Data for hull sections drawing at scale one, inc. hull frames and deck bars

Hulls storage : is the storage space for hulls input data

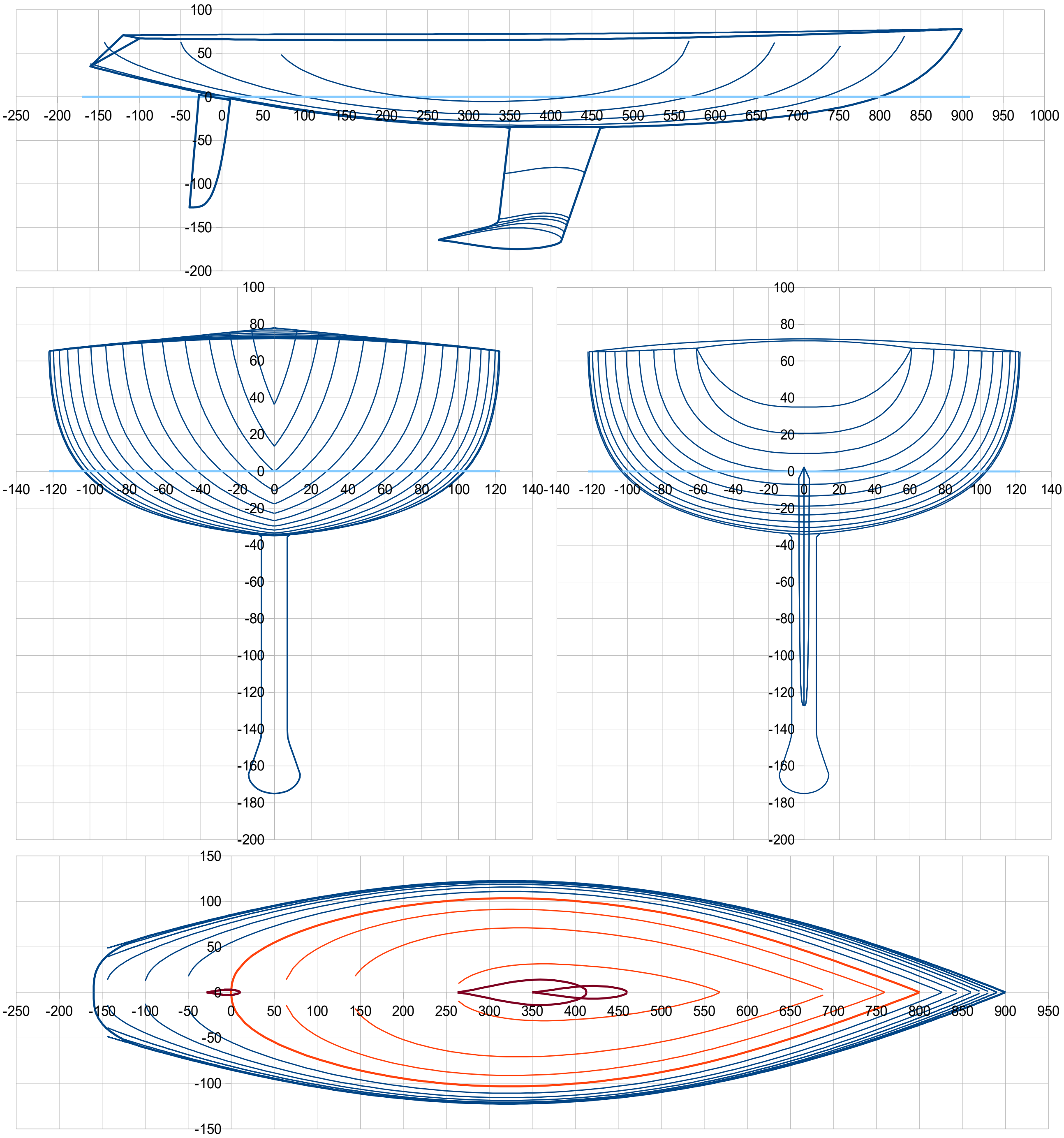
Sailplan input and output : includes an User space (input and outputs) followed by an Administrator space wher the computations are carried out

Mass spreadsheet input and output : includes an User space (input and outputs)

+ in annex of the present User Guide : main formulations involved in Gene Hull

The coordinates x,y,z used fo the views include :

- Origin 0,0,0 at the cross of the designed waterline surface (« H0 » level) and the perpendicular at the rear point of the waterline (station C0). The perpendicular at the front point of the waterline is station C10.
- x = longitudinal axis (positive towards front),
- y = transversal axis,
- z = vertical axis (positive towards up), Showed unities on the views are **cm**



Automatic scales are proposed for the views, with a main grid with a fixed pitch. Nevertheless, it is suggested for the User, as long as the main dimensions of the new project are fixed, to put the views at a right scale and to fix it.

Gene-Hull sheet / Input

1. Data to enter for the hull body

Data to enter are in column B (cells B12 to B65), the ones of the hull of reference are in column D, in pink. Simplified views of the hull are showed opposite to the data so that one can see on them, as well as on the complete views some lines below, the effect of each data new value *(sometimes these small views do not update instantly, in that case go directly to the complete views that are in the output space)*. ***Data are in metric units,*** with automatic conversion in Imperial units in column C *(in italic blue in the file).*

1.1 Hull data	metric	*>> feet*	*Hull of ref.*
Lenght of waterline :			
Lwl (m)	8,00	*26,25*	*8,00*
Maximum draft of the hull body :			
Tc (m)	0,36	*1,18*	*0,36*
X Tc (%Lwl)	50,0		*50,0*
Hull bow :			
Xbow (m)	9,00	*29,53*	*9,00*
Zbow (m)	0,78	*2,56*	*0,78*
Shape coefficient of the bow :			
Cet	7,0		*7,0*
Polynomials of the keel line, front part and rear part :			
Pui q av	2,45		*2,45*
Pui q ar	2,35		*2,35*
Rear end of the transom :			
X tab ar (m)	-1,60	*-5,25*	*-1,60*
Z tab ar (m)	0,35	*1,15*	*0,35*
Sheer line, in horizontal projection xy :			
Bg (m)	1,89	*6,20*	*1,89*
X Bg (% Lwl)	48,0		*48,0*
Alfa (°)	3,50		*3,50*
Pui liv y	2,00		*2,00*
Cor Pui liv	0,020		*0,020*
Pui Cor Pui	1,60		*1,60*
X liv ar (m)	-1,00	*-3,28*	-1,00
Scow	0,00		0,00
Option Hard Chine line, in vertical projection xz :			
Type	0		0
1,2 Zhc av (m)	0,75	*2,46*	0,75
2 Zhc m (m)	0,20	*0,66*	*0,20*
1,2 Zhc ar (m)	0,42	*1,38*	*0,42*
Pui hc z	2		*2*
Sheer line, in vertical projection xz :			
Z liv m (m)	0,65	*2,13*	*0,65*
Z liv ar (m)	0,67	*2,20*	*0,67*
Pui liv z	2,0		*2,0*
Deck / central line rear end			
Z p m (m)	0,72	*2,36*	*0,72*
X p ar (m)	-1,20	*-3,94*	*-1,2*
Z p ar (m)	0,7	*2,30*	*0,70*
Pui pont z	2,0		*2,0*
Sections : as a combination of « V » shape and « E » sh			
Sections V :			
C Hv av	4,17		*4,17*
C Hv m	4,62		*4,62*
C Hv ar	6,82		*6,82*
Pui Hv	3,00		*3,00*
Pui V av	6,00		*6,00*
Pui V ar	28,00		*28,00*
Pui Pui V	1,30		*1,30*
Cor Pui Pui V	0,50		*0,50*
Sections E and combination VE :			
Pui E	3,00		*3,00*
mix VE av	1,00		*1,00*
mix VE ar	0,00		*0,00*
Pui mix VE	1,00		*1,00*

Lenght of waterline

Lwl (m) : lenght of waterline at H0 **(cell B12)**

Rear perpendicular crosses H0 plan at the coordinates origin (0, 0, 0). Front perpendicular crosses H0 at (Lwl, 0,0) point.

Hull body draft

Tc (m) : maximum draft of the hull body **(cell B14)**

X Tc (%Lwl) : longitudinal position of the maximum draft (in % of Lwl) **(cell B15)**

Bow end

Xbow (m) : should be > Lwl (inverted bow is not possible) **(cell B17)**

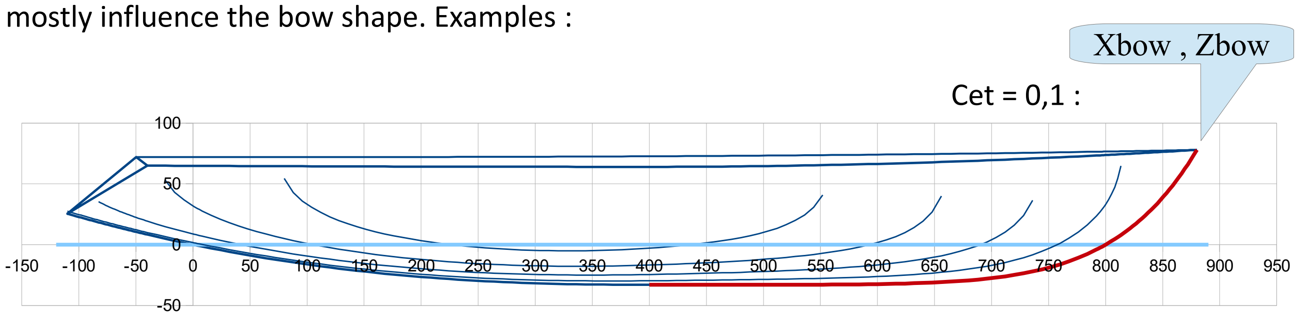
Zbow (m) : it is the front freeboard **(cell B18)**

Bow coefficient

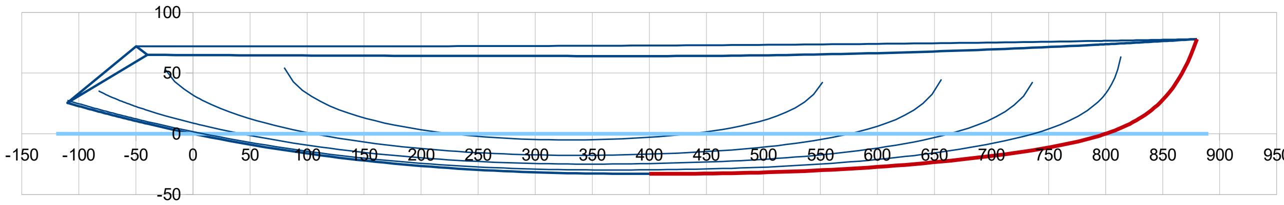
For the bow shape, 3 data are influent and in interaction : **Xbow** (acting on the front overhang), **Cet** (acting on the bow line) and **Pui q av** (acting on the overall shape of the front keel line).

Cet : adimensional coefficient > 0, from 0,1 to 100 typically. **(cell B 20)**
This coefficient is involved in the polynomial formulation of the front part of the keel line and mostly influence the bow shape. Examples :

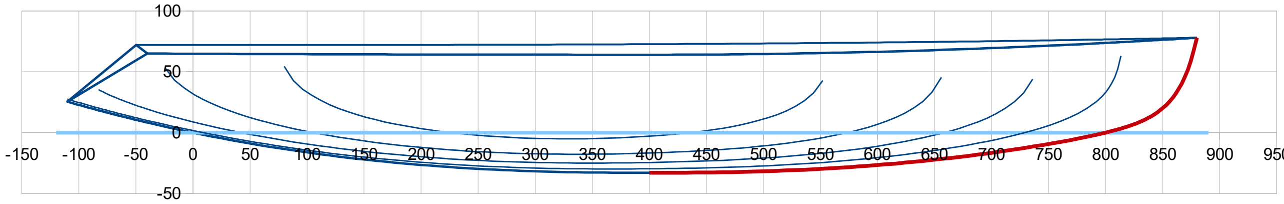
Cet = 0,1 :



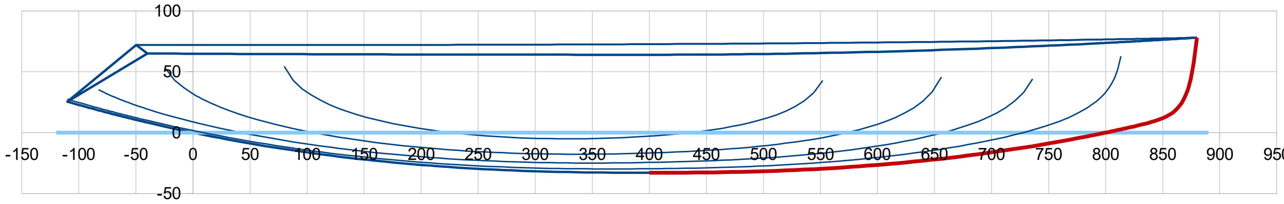
Cet =10 :



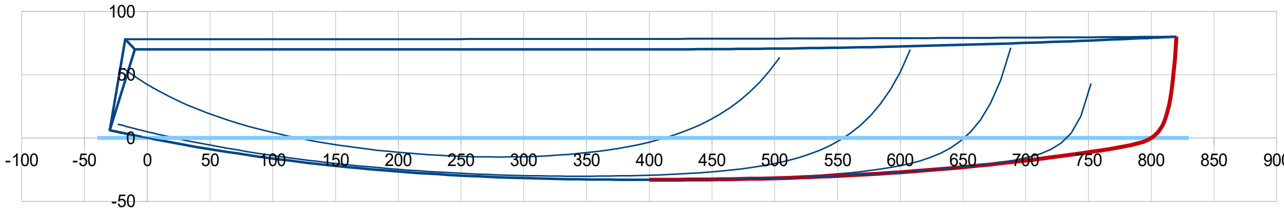
Cet 20 :



Cet 50 :



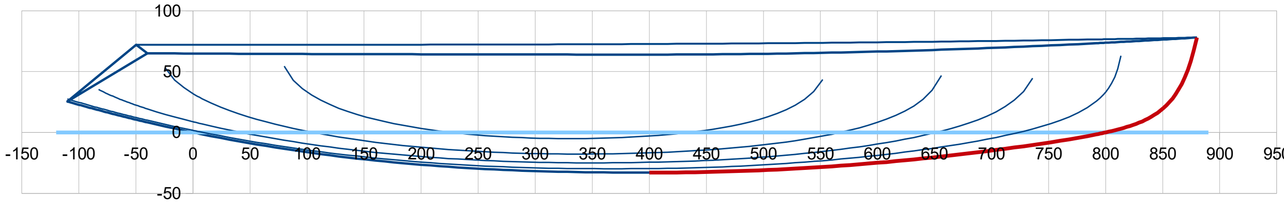
Cet 50 with a shorter front overhang :



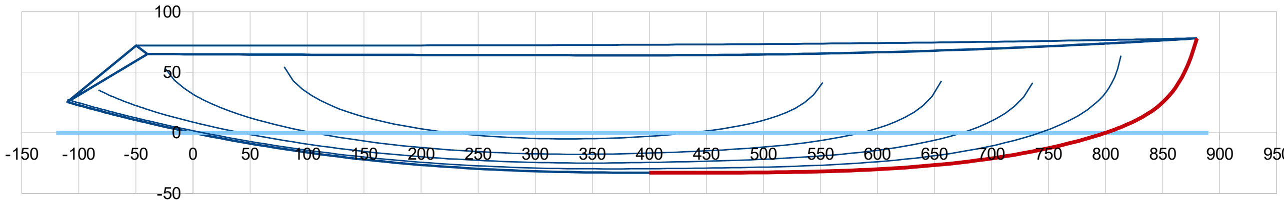
Keel line polynomial / front part (x > X Tc)

Pui q av : adimensional coefficient which figures the power factor of the front polynomial (details of the formulation in the technical appendix on request). **(Cell B22)**
Should preferably be ≥ 2 , some examples :

Pui q av = 2 :



Pui q av = 3,5 :



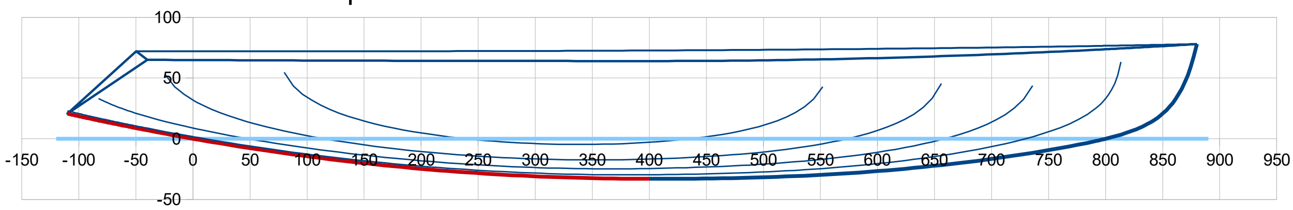
Keel line polynomial / rear part (x < X Tc)

For the rear keel line shape, 3 data are influent and in interaction : **X tab ar**, **Z tab ar** (= the rear

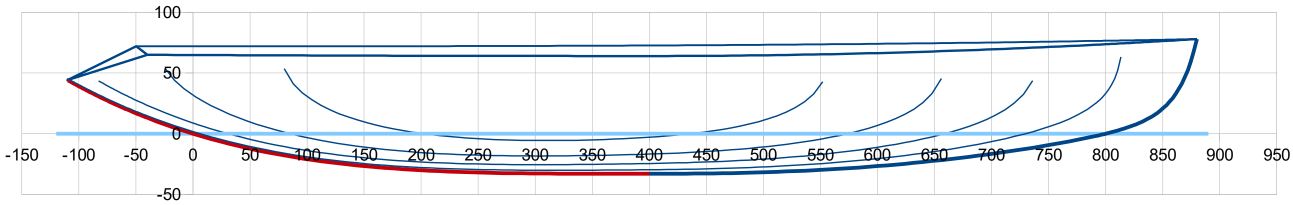
point location) and **Pui q ar** (acting on the overall shape of the rear keel line).

Pui q ar : adimensional coefficient which figures the power factor of the rear polynomial (details of the formulation in the technical appendix on request). **(cell B23)**
Should preferably be ≥ 2 , some examples :

Pui q ar : 2



Pui q ar : 3,5



Rear transom end point

X tab ar (m) : X of the rear point overall, should be less than all other X. **(cell B25)**

<u>Nota</u> : an inverted rear transom is modelled, implying the respect of this condition :

X tab ar < X p ar < X liv ar < 0

Z tab ar (m) : Z of the rear point. **(cell B26)**
This data influence the shape of rear end of the the keel line. Example :

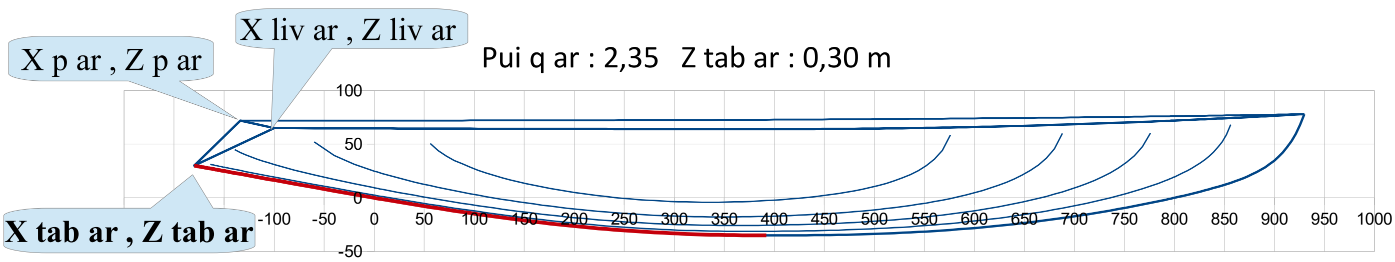


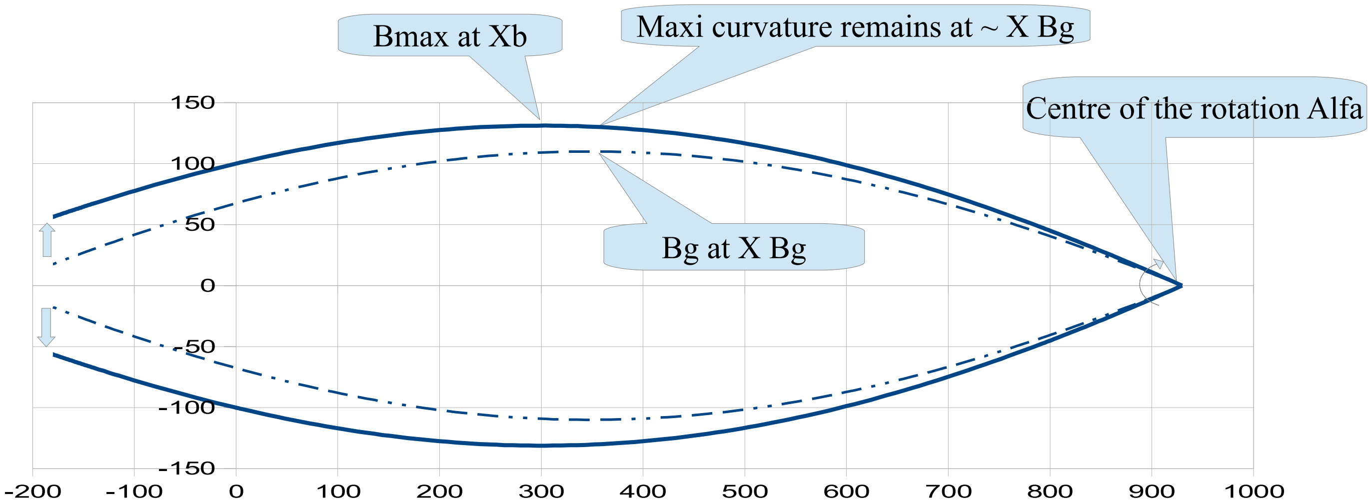
Fig. 1

Sheer line in horizontal plan (plan xy)

An indirect approach is proposed to define the sheer line projection in the horizontal plan, using 3 data : **Bg (m) , X Bg (%Lwl) and Alfa (°).** This approach allows both to adjust the rear transom width and to position the maximum beam Bmax independently of the sheer line

maximum curvature.

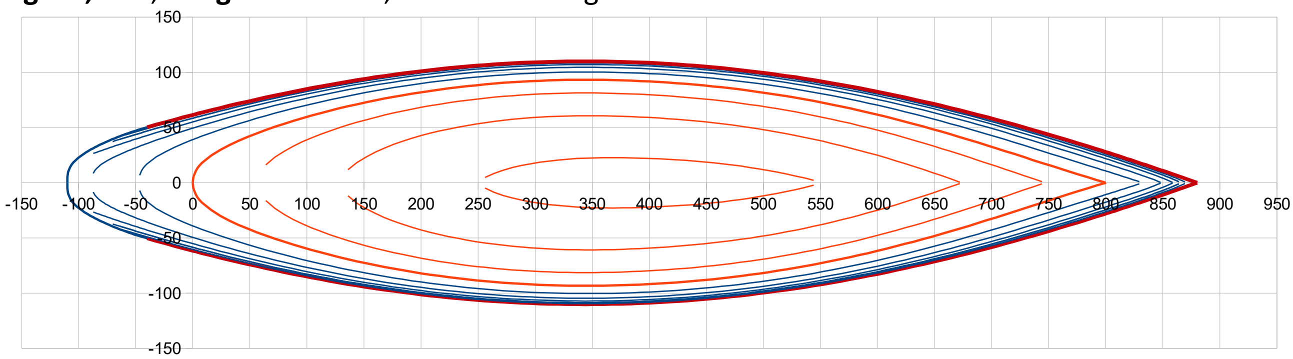
At first a virtual sheer line (dashed line here below) is defined with as input the maximum beam **Bg (m) (cell B28)** positioned in **X Bg (%Lwl) (cell B29)**. Then, this line is « open » by rotation of a half-angle **Alfa (°) (cell B30)** with the bow end as center for this rotation (as showed here below), to obtain the real sheer line with a new maximum beam **Bmax** at a new location **Xb** (Bmax and Xb being computed by the system and showed in blue opposite to the input data). So a set of values for Bg, X Bg and Alfa leads to the real sheer line with maximum beam Bmax at a real position Xb. By doing so, the sheer line maximum curvature remains close to X Bg and is disconnected to



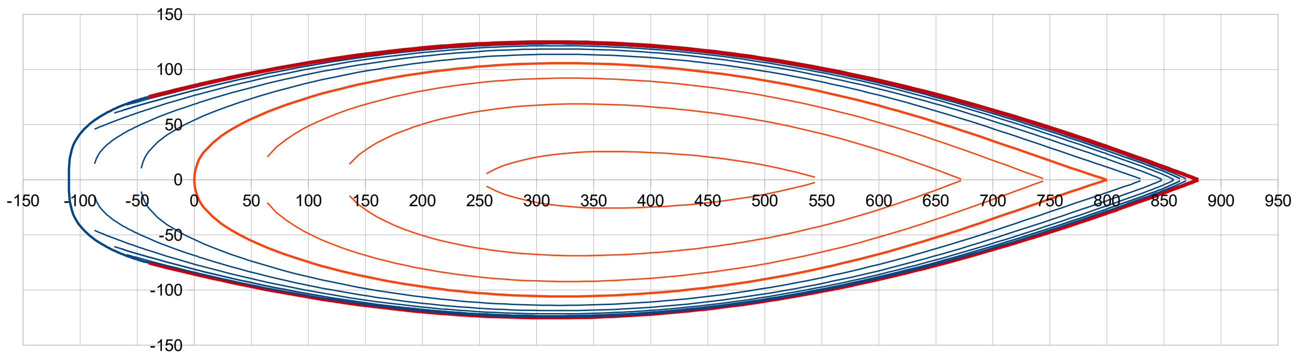
Nota : this « Alfa » reshaping of the hull is powerful, it can be done at any moment of the hull definition, all the stations and waterlines are automatically updated.

Example 1 :

Bg = 2,2 m ; **X Bg = 43 % Lwl** ; Alfa = 0° >>> generic hull

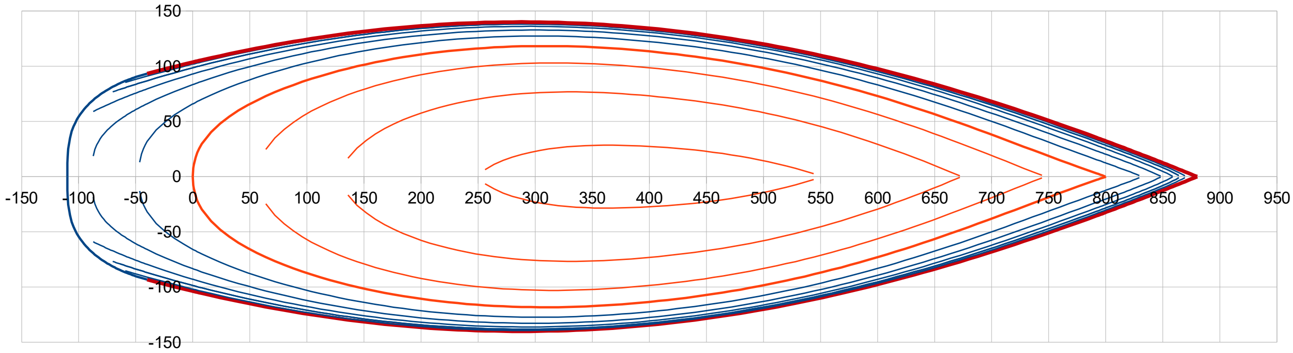


… + **rotation Alfa = 1,55°** >>> real hull with **Bmax = 2,5 m** at **Xb = 39 %Lwl**

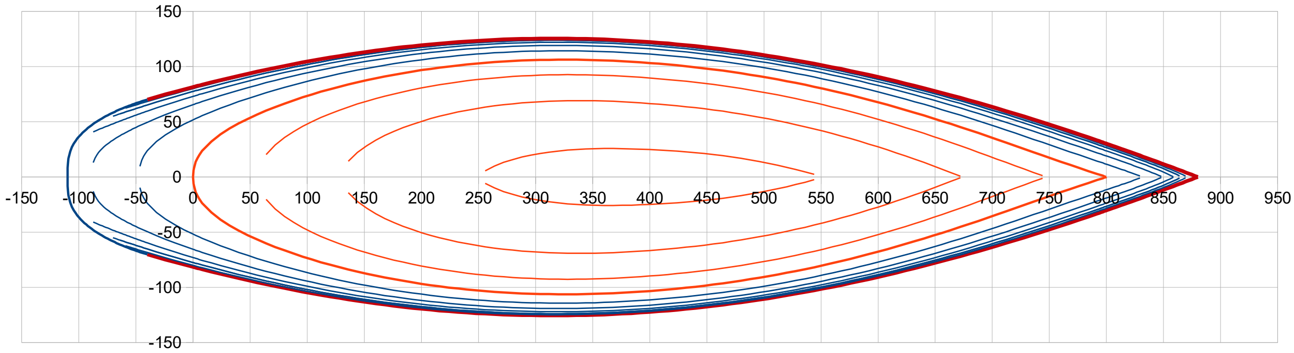


One can just use Alfa = 0°, or even adopt an inverted approach with a negative value of Alfa >>> **Exemple 2:**

Bg = 2,8 m ; **X Bg = 36 %Lwl** ; Alfa = 0° >>> generic hull

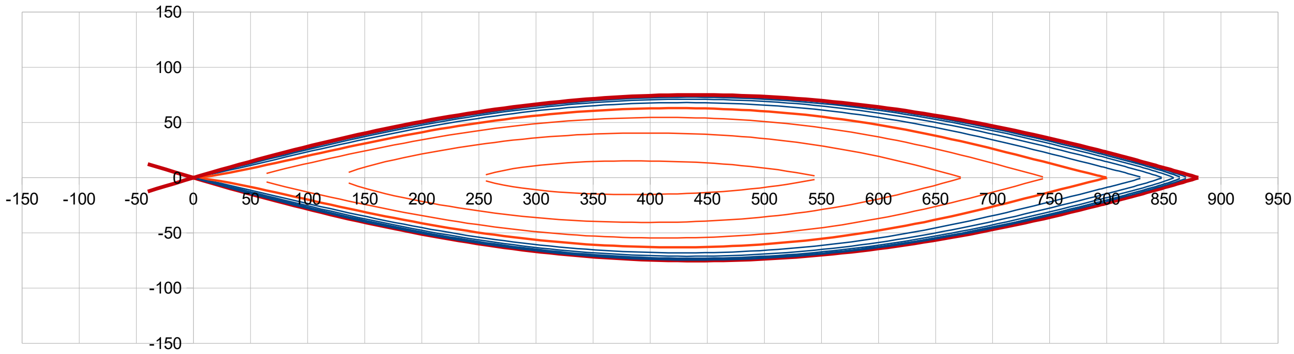


... + **rotation Alfa = -1,45°** >>> Real hull **Bmax = 2,5 m** at **Xb 39 % Lwl**

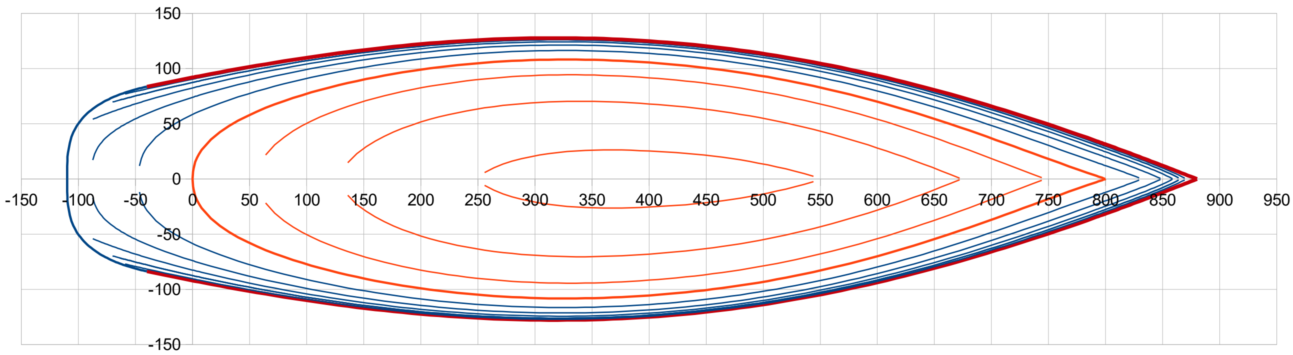


The generic hull could even be virtual but yet be transformed into a real one by application of a great enough Alfa >>> **Exemple 3 :**

Bg = 1,5 m ; **X Bg = 55 %Lwl** ; Alfa = 0° >>> generic hull



... + **rotation Alfa = 6°** >>> Real hull **Bmax = 2,55 m** at **Xb 40 % Lwl**



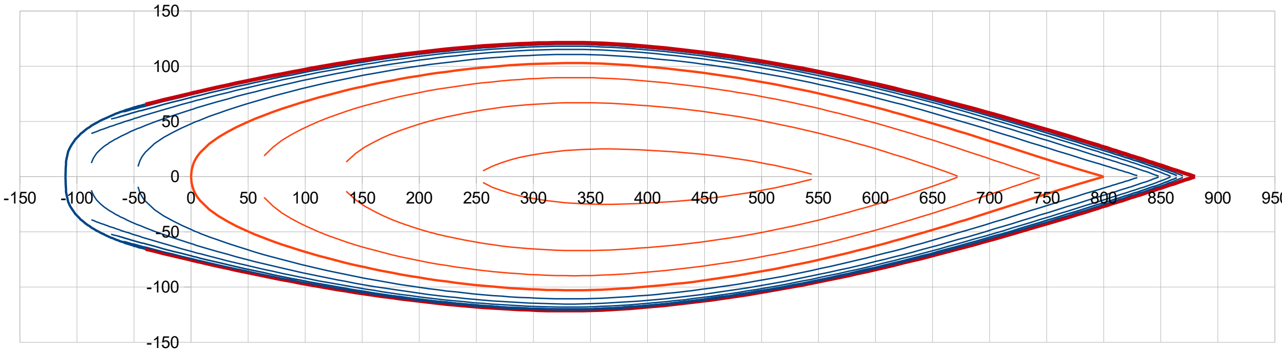
In each case the maximum curvature of the sheer line remains close to X Bg of the generic hull :
>>> Exemple 1 : 43% Lwl ;   Exemple 2 : 36 % Lwl ;   Exemple 3 : 55 % Lwl

Nota : the « rotation » is explained in the technical appendix, actually concerning only the y values of the sheer line, the x values being unchanged (the rotation matrix is used only for the y values).

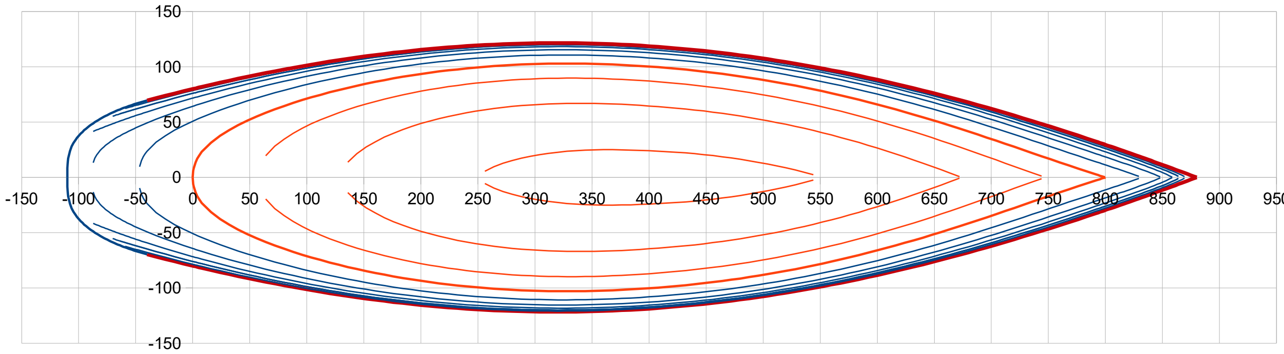
Pui liv, **Cor Pui liv** and **Pui Cor Pui** are 3 adimensional coefficients for respectively the power of the sheer line polynomial, its correction along with x and the power of the correction polynomial itself (formulation details in the technical appendix).

Pui liv (cell B31) :
Pui liv = 2 gives the better curvature regularity in the midship zone, it is the recommended value.
Pui liv < 2 lead to a more accentuated curvature (up to a folding when Pui liv < 1,5) and on the other hand a Pui liv > 2 lead to a flattening in the midship zone. Exemples :

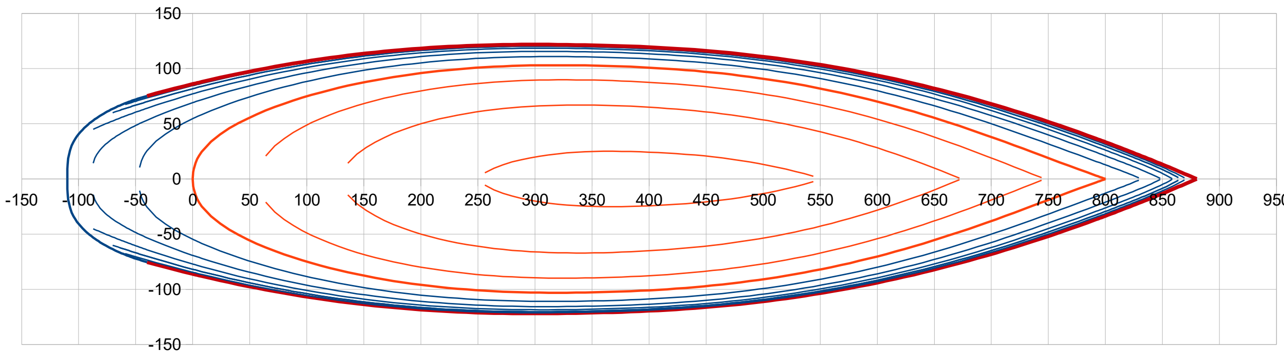
Pui liv = 1,8 :



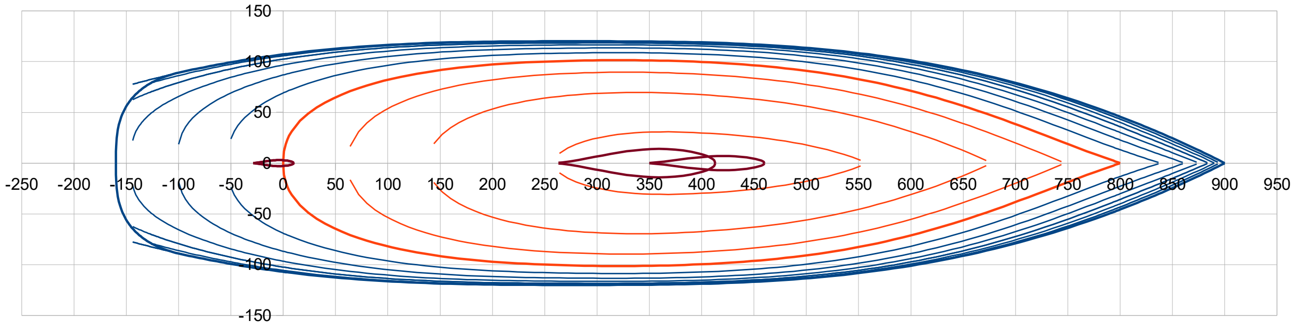
Pui liv = 2 :



Pui liv = 2,3 :

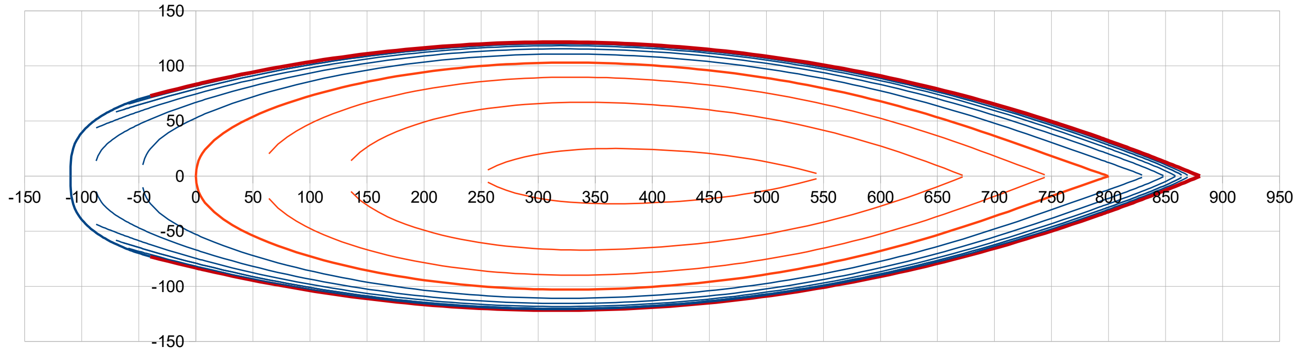


… up to a « barge » like shape when using Pui liv = 3 :

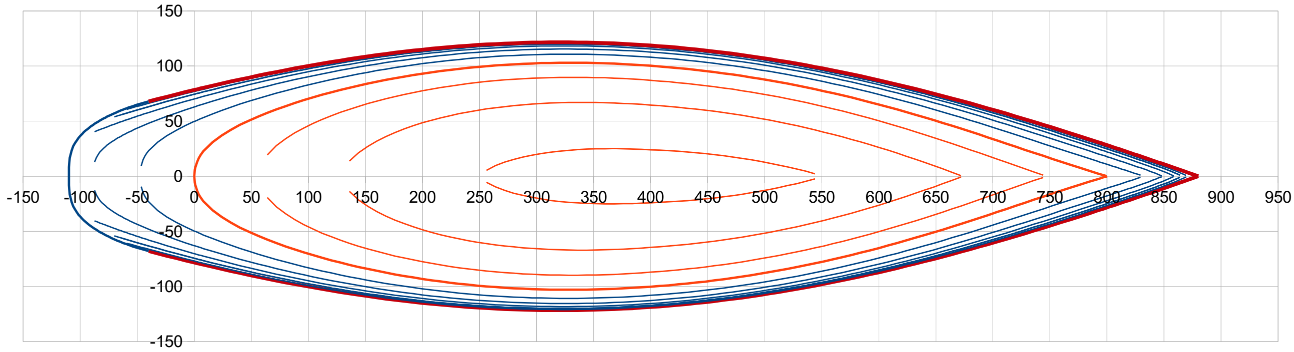


Cor Pui liv (cell B32) can add more or less tension towards the front anf aft ends of the sheer line, meaning ends with less curvature. Examples :

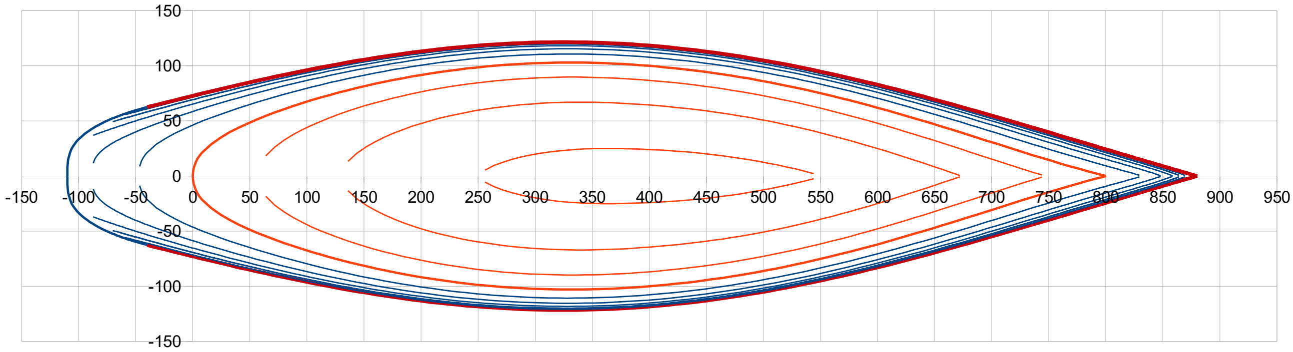
Cor Pui liv = 0



Cor Pui liv = 0,03



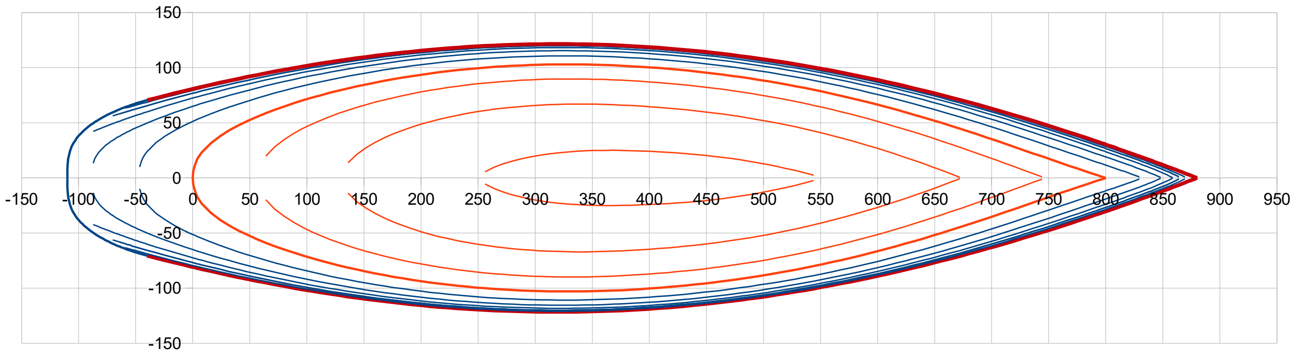
Cor Pui Liv = 0,06 :



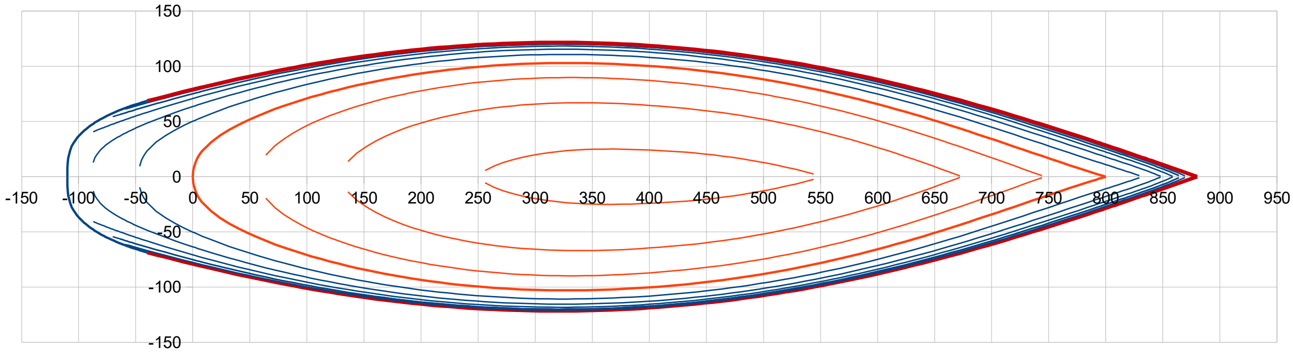
Negative values of Cor Pui Liv can be tested too, with the inverted effect.

Pui Cor Pui (cell B33) acts on the application with x of the correction Cor Pui liv.
Pui Cor Pui =1 >>> correction application is linear.
Pui Cor Pui > 1 >>> amplifies the correction application towards the ends. Some examples :

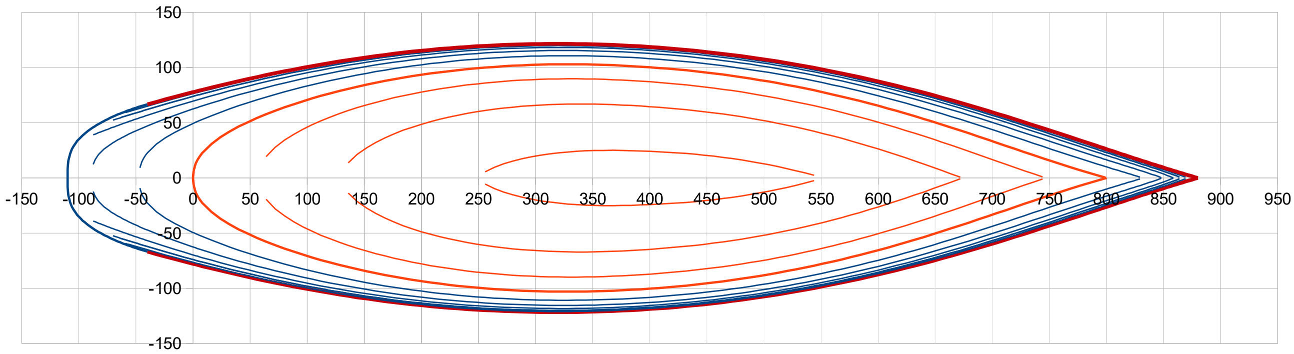
Pui Cor Pui = 1



Pui Cor Pui = 2,5



Pui Cor Pui = 5



<u>Nota :</u> with recommended values of 0,5 to 2, Pui Cor Pui acts as a fine tuning of the tensioning of the ends of the sheer line triggered by Cor Pui liv.

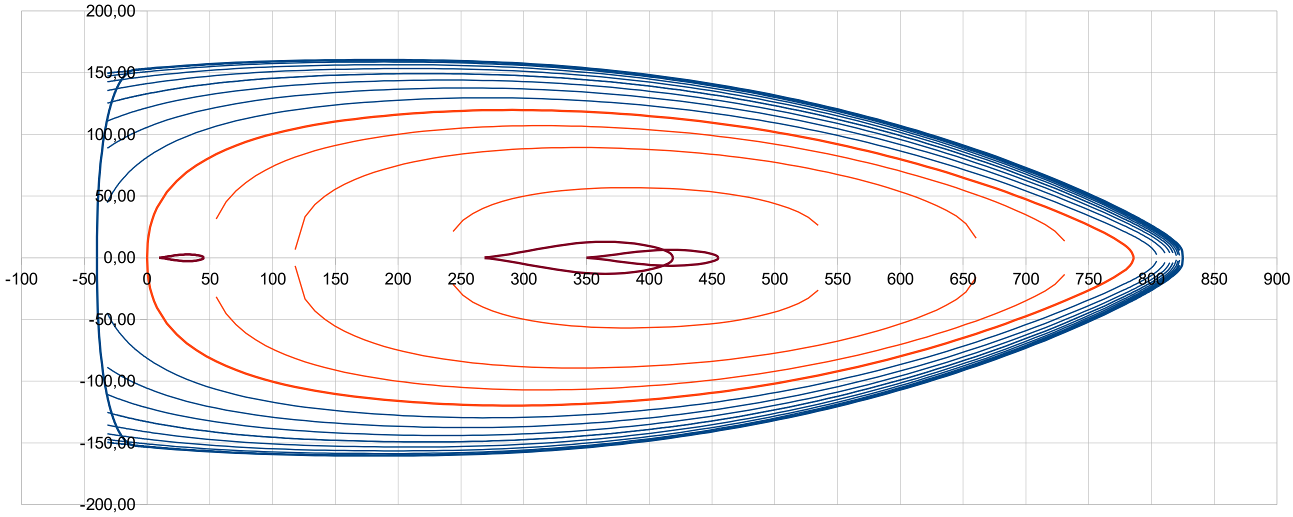
X liv ar (m) (cell B34) : it is the X position of the rear point of the sheer line (see Fig. 1 page 8). Condition to fullfil : X liv ar < 0 and > X p ar. X liv ar is the position taken for the draw of the station named Car 1 .

Nota : Y value of the sheer line aft point is not specified, as it results from the 6 previous

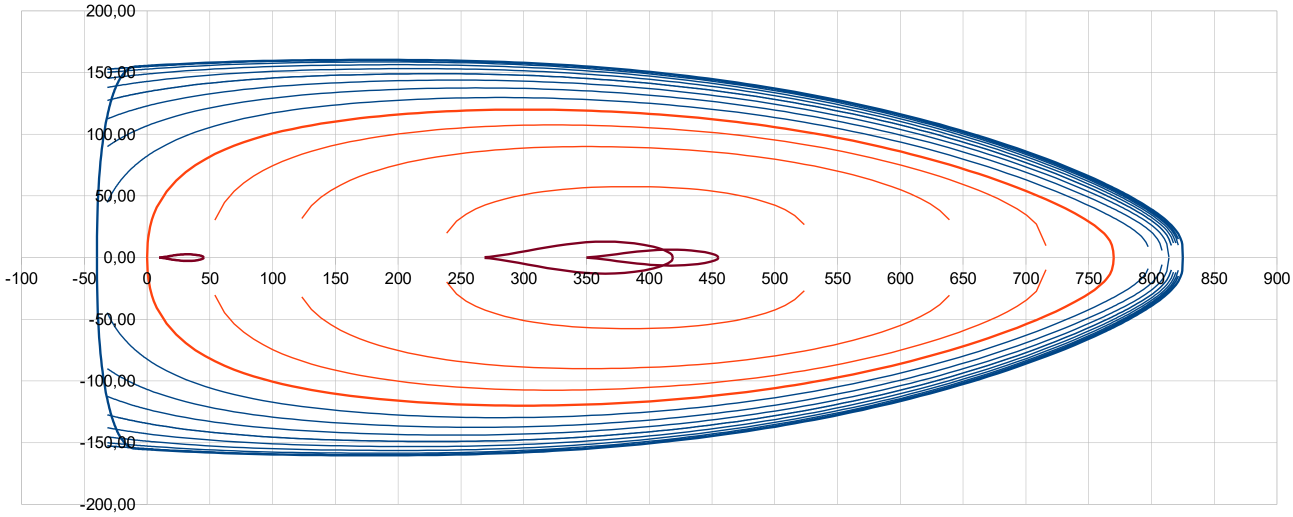
parameters here above detailed.

Scow : it is a coefficient introducing a scow influence on the bow shape of the sheer line.
Scow = 0 to 1 ; ***0 = no scow bow*** ; ***1 = full « rectangular » size scow bow***

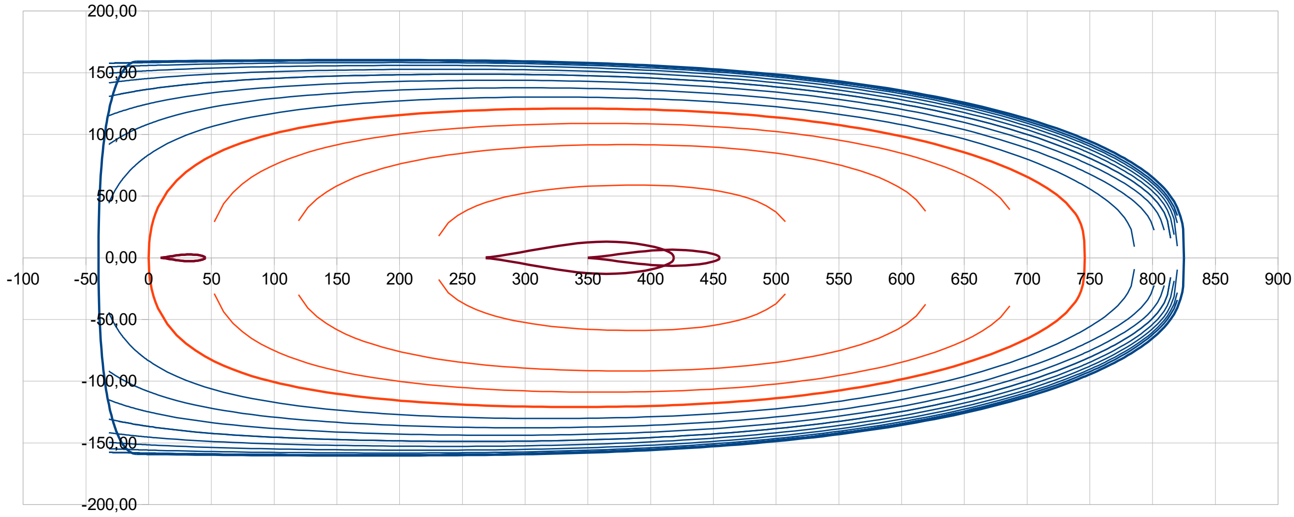
Example with Scow = 0,2



Example with Scox = 0,4



Example with Scow = 0,8



Option Hard chine line, its definition in the vertical projection (xz plan)

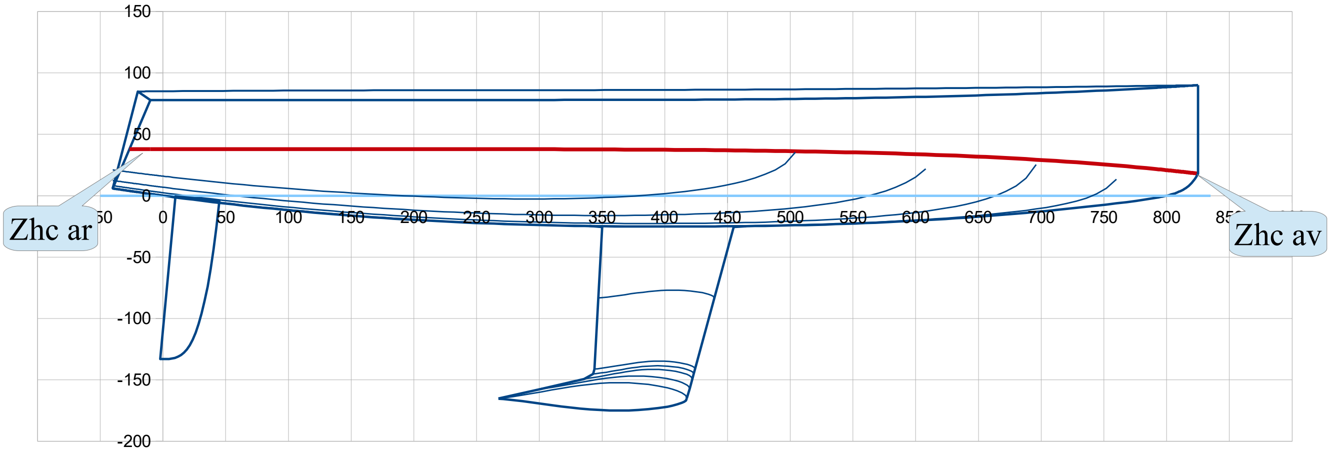
Type : 0 = no hard chine ;
1 = hard chine defined by 2 heights ;
2 = hard chine defined by 3 heights ;

When Type = 1 , two data to input :
1,2 **Zhc av (m):** height of the hard chine line at the bow **(cell B38)**
1,2 **Zhc ar (m) :** height of the hard chine line at the aft **(cell B40)**

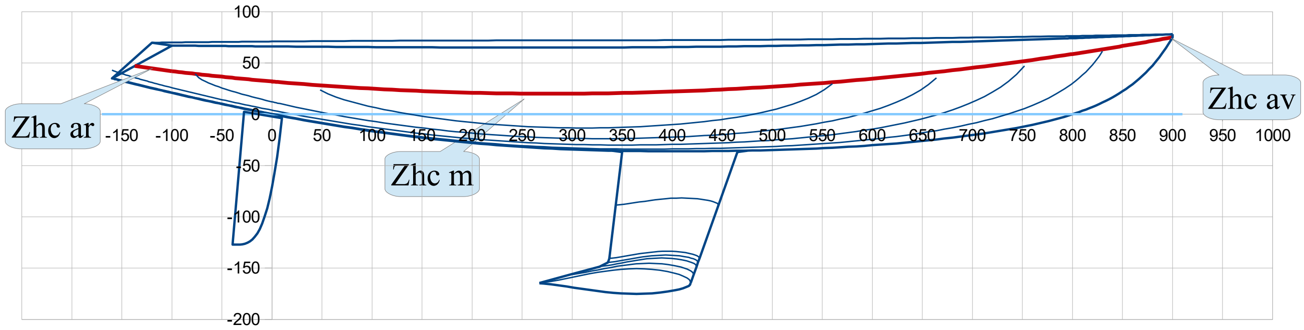
When Type = 2, a third height is to input :
2 **Zhc m (m) :** height of the hard chine line at 35% Lwl **(cell B39)**

Pui hc z : power of the polynomial defining the hard chine line, should be >1 **(cell B41)**

Example Type 1 (2points) with Zhc av = 0,18 m ; Zhc ar = 0,38 m ; Pui hc z = 5



Example Type 2 (3points) with Zhc av = 0,42 m ; Zhc m = 0,20 m ; Zhc ar = 0,75 m ; Pui hc z = 2

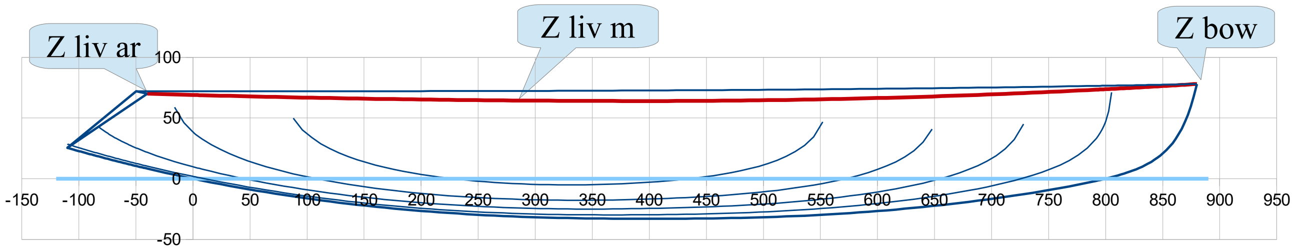


Sheer line, its definition in vertical projection (xz plan)

Z liv m (m) : it is the freeboard at 35% Lwl **(cell B43)**
Z liv ar (m) : it is the aft freeboard, specified at the sheer line aft point. **(cell B44)**

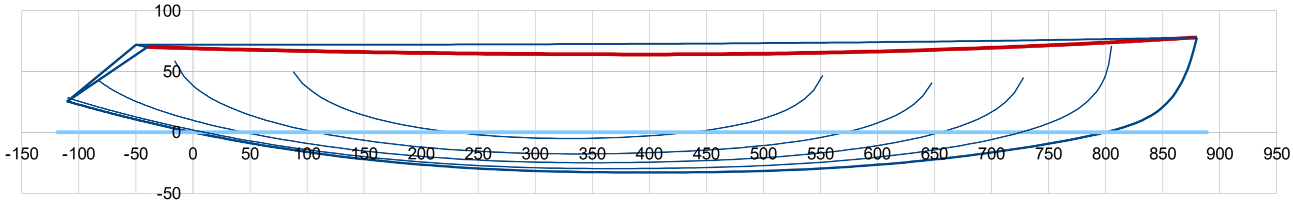
Together with **Z bow** defined here before, these are the 3 freeboards on which leans the xz

polynomial for the sheer line definition.

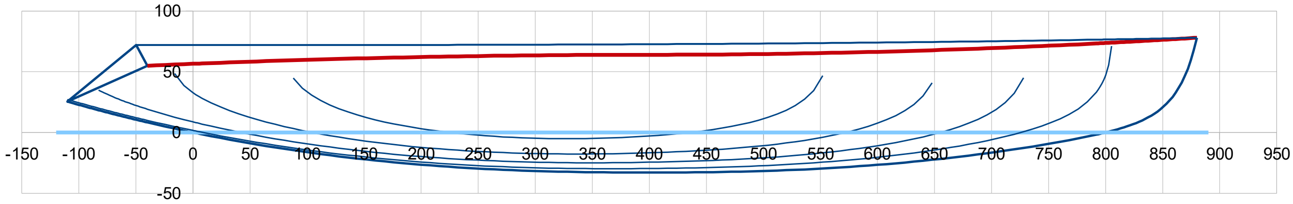


Pui liv z : it is the power of this polynomial for the fore part of the line. **(cell B45)**
Usual values : 2 to 3.

Examples with two different values of Z liv ar :
Z bow : 0,78 ; Z liv m = 0,64 ; **Z liv ar = 0,70** ; Pui liv z = 2 :



Z bow : 0,78 ; Z liv m = 0,64 ; **Z liv ar = 0,55** ; Pui liv z = 2 :

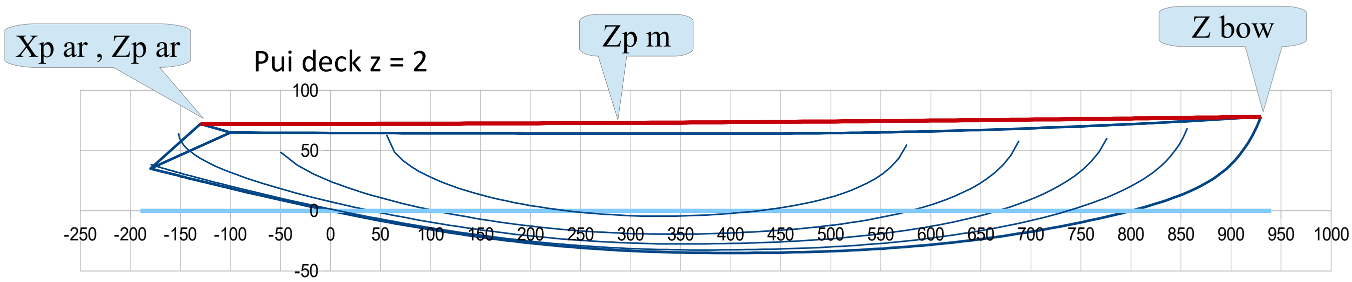


Deck / central line of symmetry

A deck surface is made of transversal circular arcs based on both the sheer line definition and the central line of symmetry (at y = 0) going from the front end of the hull (X bow, Z bow) and defined by :

- a point at midship : **Zp m (m)** at X = 35% Lwl **(cell B47)**
- a point at the rear end of the deck : **Xp ar (m) , Zp ar (m)** **(cells B48 & B49)**

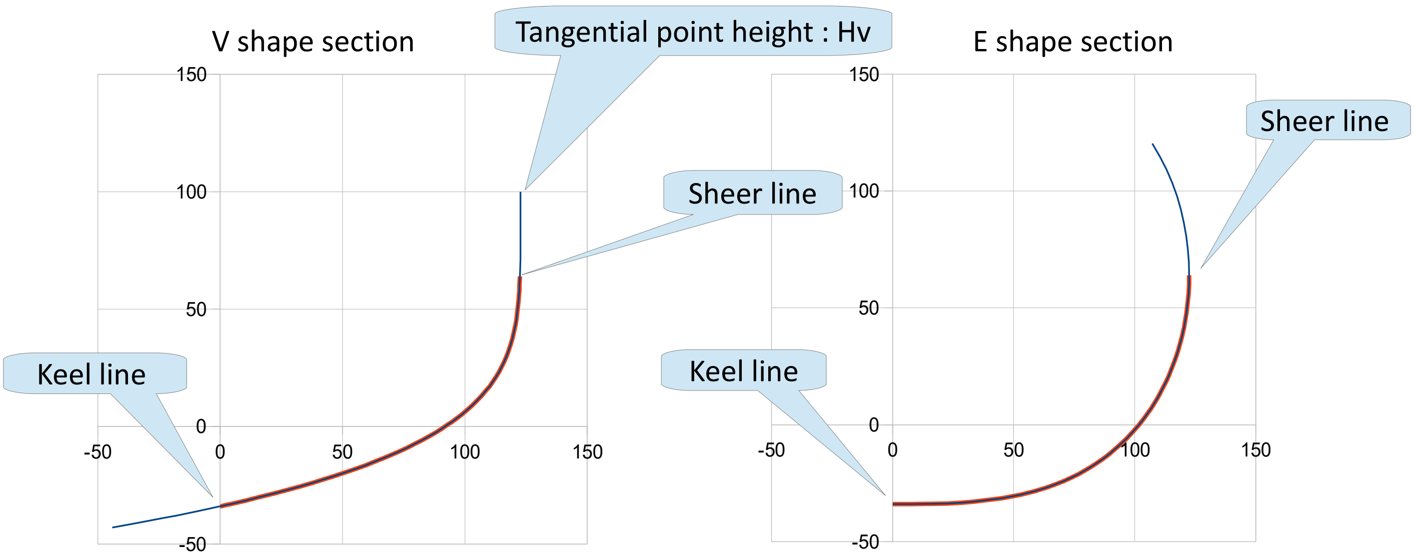
Pui deck z (Case B50) : it is the power of the polynomial defining the fore part of this deck central line. Recommended value : 2 à 3. Example :



VE Sections (as a combination of « V » and « E » transversal shapes)

In the « VE » spreadsheet application, the transversal sections are defined as a combination of 2 polynomials, one representative of a V shape section and another one representative of a E shape section (E for Elliptic). In the « UE » application, combination of U shape section and of E shape section. Before describing each input parameters, some more explanation and illustration of these combinations are probably useful.

For the VE file, sections are combination of these two shapes sketched here below. Adimensionnal parameters to enter concern the height of the tangential point Hv, the degree and the coefficients of the polynomials V and E, their variation with x.



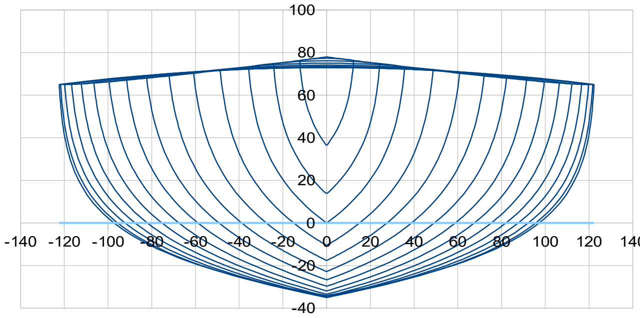
Adimensional parameters for the V shape :

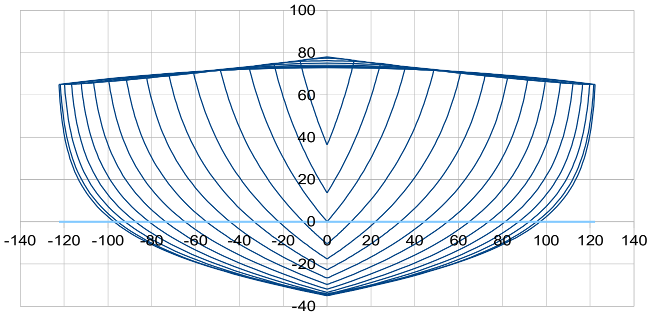
C Hv av ; C Hv ar ; C Hv m ; Pui Hv (cells B53, B54, B55, B56)

These parameters deal with the height Hv of the polynomial tangential vertical point as a function of the x position of the section (formulation details in the technical appendix).
C Hv av at bow end , **C Hv m** at midship and **C Hv ar** at rear end, are the relative heights Hv to respectively Z bow, Z liv m and Z liv ar and **should be > 1,1** . The larger C Hv, the more the V shape is sharp ; the smaller C Hv, the more the V shape is rounded.
Pui Hv is the power of the polynomial computing the evolution of C Hv from front to rear of the boat.

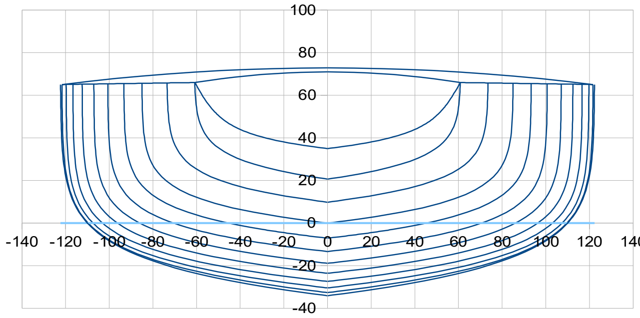
Some examples (V sections only, without the combination with E sections) :

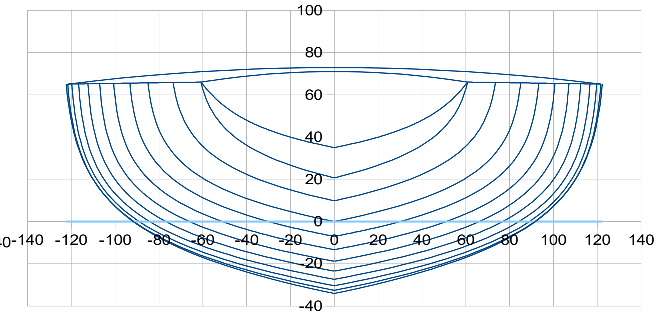
C Hv av = 1,5 ; C Hv m = 6 ; C Hv ar = 6 >>> **C Hv av = 6** ; C Hv m = 6 ; C Hv ar = 6





C Hv av = 6 ; **C Hv m= 4 ; C Hv ar = 4** >>> C Hv av = 6 ; **C Hv m= 7 ; C Hv ar = 7**

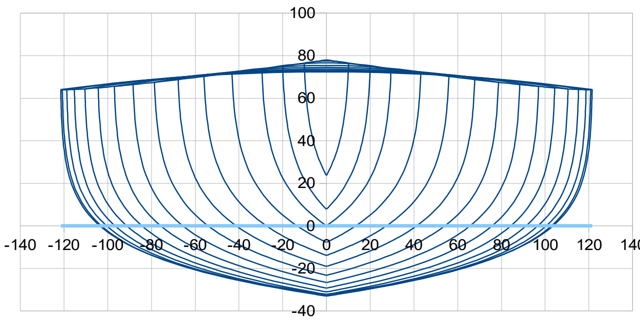


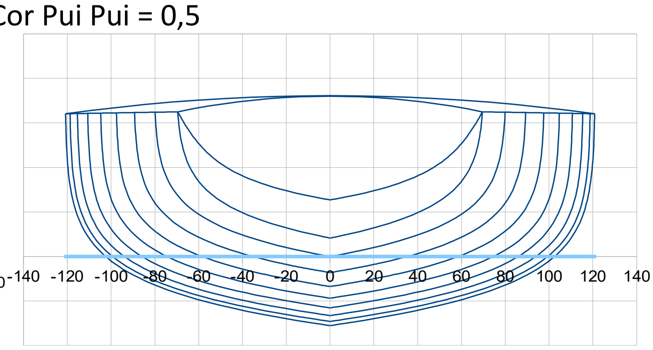


Pui V av ; Pui V ar ; Pui Pui V ; Cor Pui Pui (cells B57, B58, B59, B60)

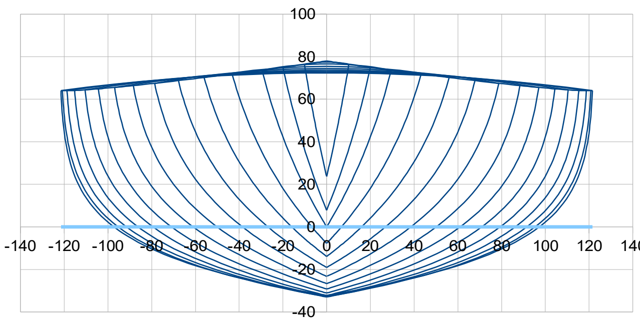
These parameters deal with the power of the polynomial with position x of the section (formulation details in technical appendix). **Pui V av** is the front power ; **Pui V ar** is the rear power. <u>The larger Pui V, the more the V shape is rounded</u>. **Pui Pui V** is the power of the polynomial computing the evolution from Pui V ar to Pui V av, and **Cor Pui Pui** is a variation with x of this power. Cor Pui Pui can be considered as a fine tuning. Some examples (V sections only, without the combination with E sections) :

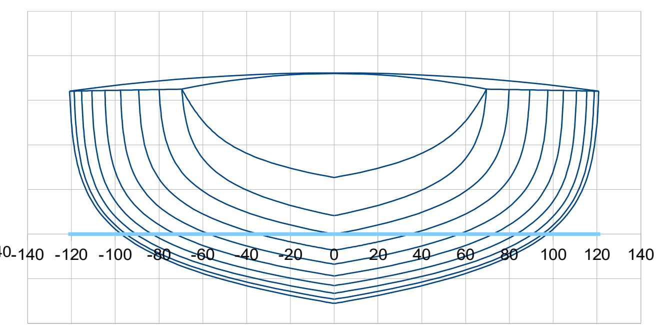
Pui V av = 13 ; Pui V ar = 28 ; Pui Pui V = 1,5 ; Cor Pui Pui = 0,5



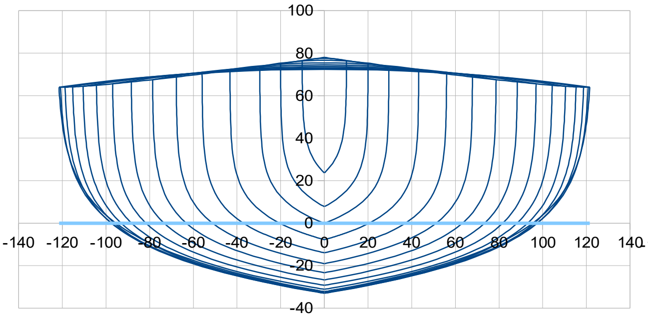


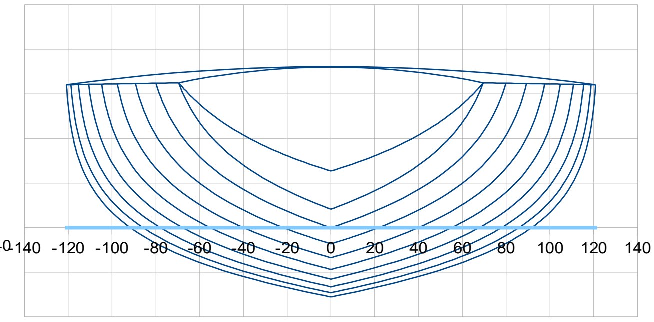
Pui V av = 2 ; Pui V ar = 28 ; Pui Pui V = 1,5 ; Cor Pui Pui = 0,5





Pui V av = 28 ; Pui V ar = 13 ; Pui Pui V = 1,5 ; Cor Pui Pui = 0,5



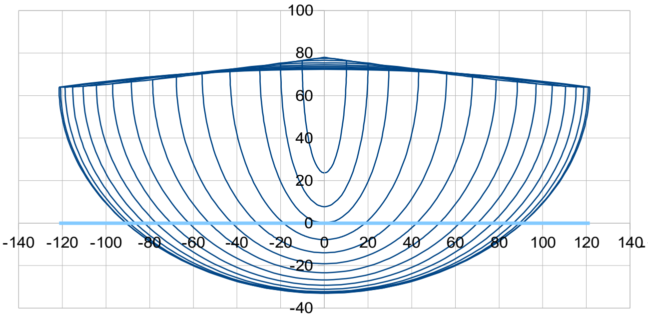


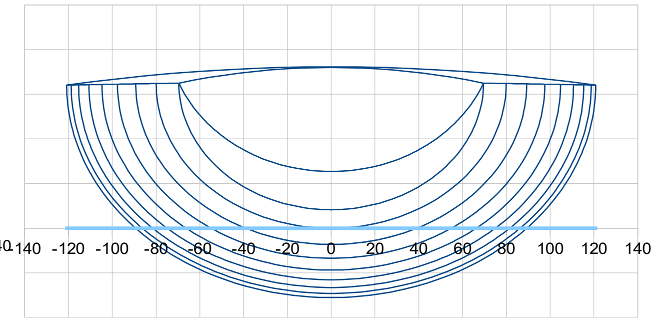
<u>E shapes adimensional parameters</u> :

Pui E : power of the E function. **(cell B62)**

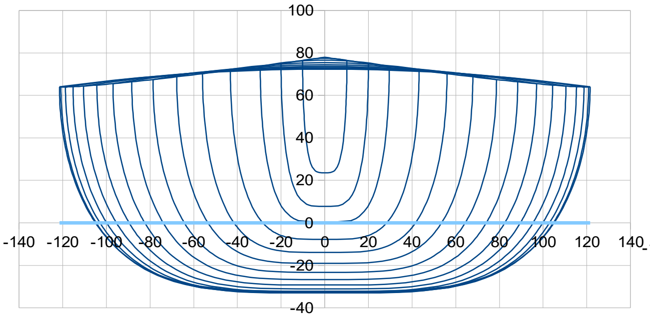
Some examples (E sections only, without combination with V sections). Examples :

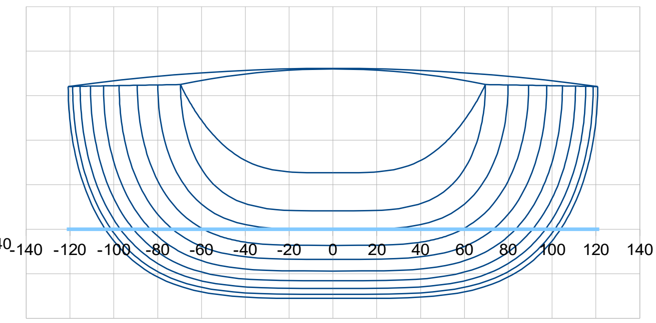
Pui E = 2





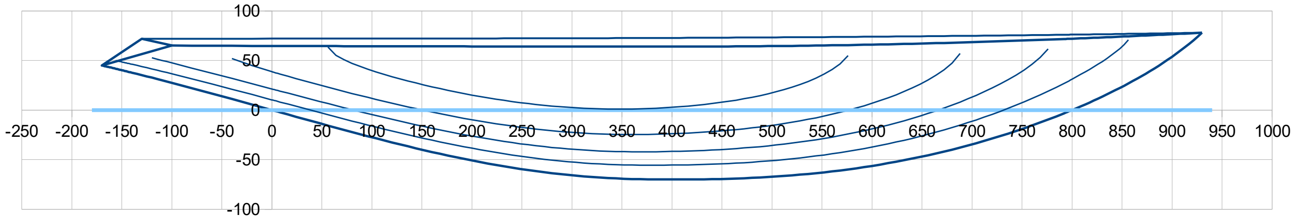
Pui E = 4

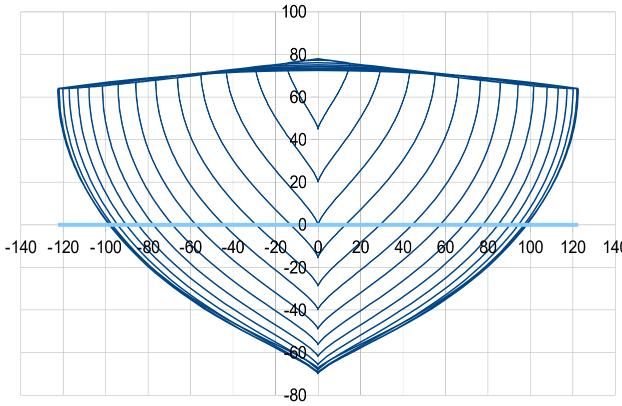


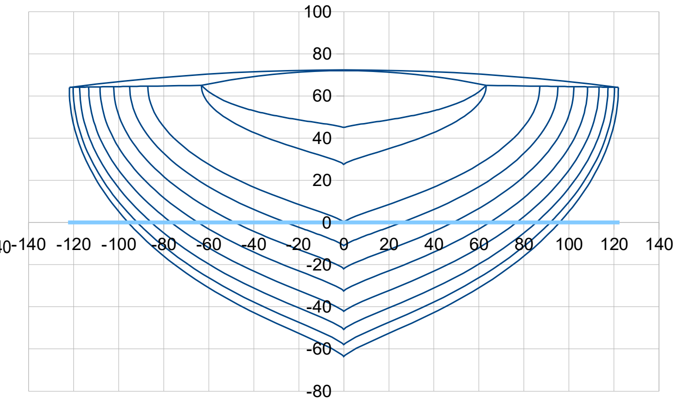


One can also generate very classic hull shape by using unusual values of Pui E < 1 :

Pui E = 0,5





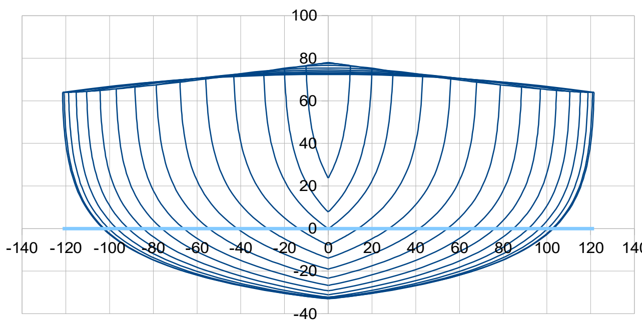


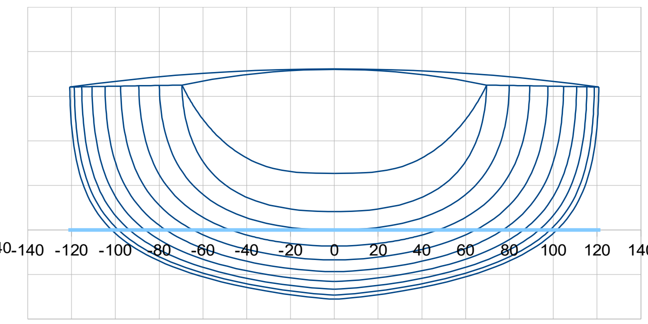
<u>V and E sections combination </u>:

V et E sections are combined in function of x, with :

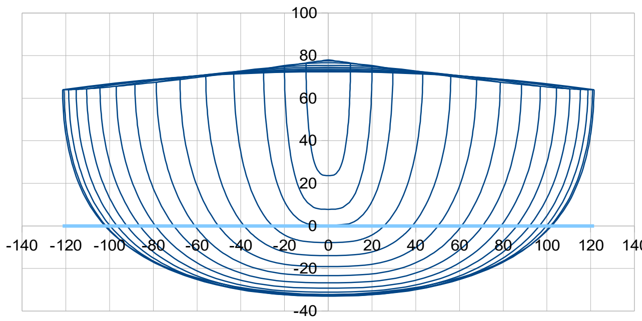
mix VE av ; mix VE ar : adimensionals between 0 to 1. **(cells B63 and B64)**
1 means 100% V shape and 0 means 100% E shape.

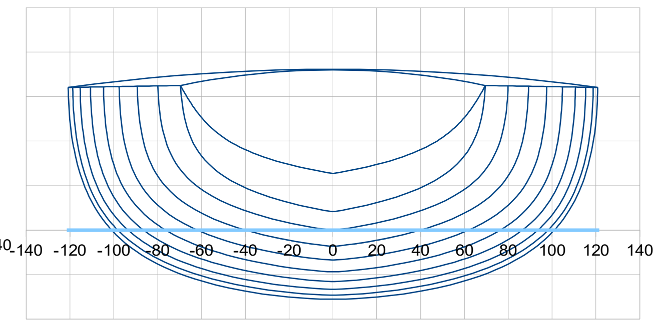
mix VE av = 1 and mix VE ar = 0 >>> Evolution from V sections at the front to E sections at the rear of the hull , it is the usual case.





mix VE av = 0 et mix VE ar = 1 >>> It is the exact contrary, evolution from E sections at the front to V sections at the aft of the hull.





Nota : all intermediate cases, i.e. mix VE av and mix VE ar between 0 and 1, are also possibles.

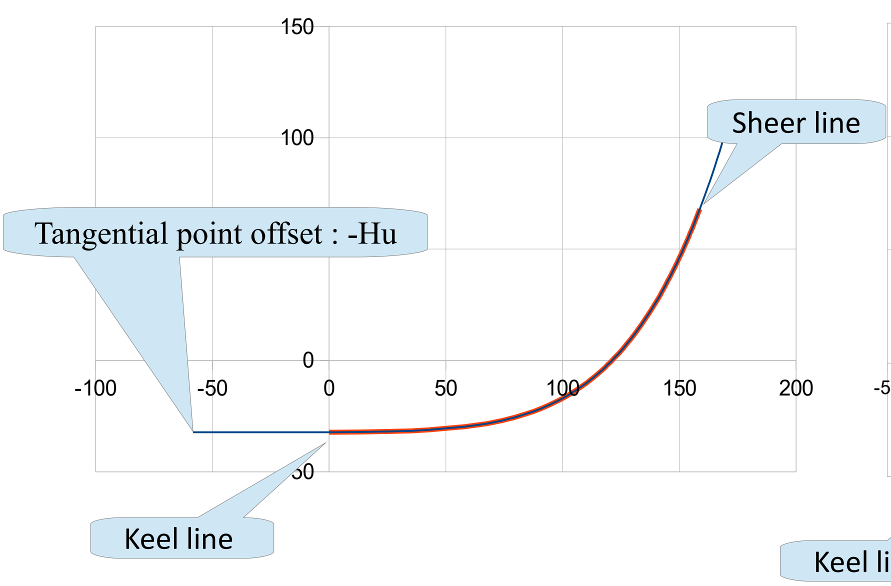
Pui mix VE (cell B65) : adimensional, it is the power of the polynomial function with x wich pilots the evolution from **mix VE av** at front end to **mix VE ar** at rear end of the hull.

UE sections (combination of U and E sections)

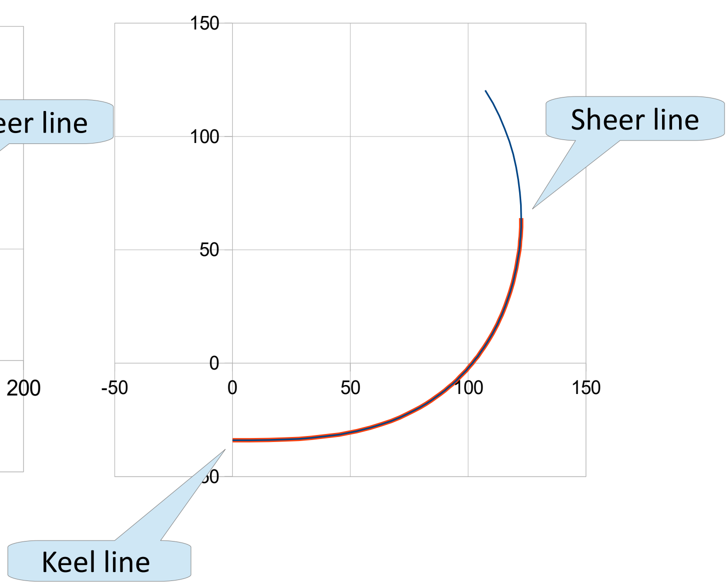
<u>For the UE file</u> :

As for VE sections, UE sections are defined as a combination of 2 polynomials, one representative of a U shape section and the other one representative of a E shape section. Data to enter concern respectively the U parameters, the E ones and their combination all along X, from front to aft end of the hull. These two last points being identical as for VE, they are not described again in this chapter.

U shape section



E shape section

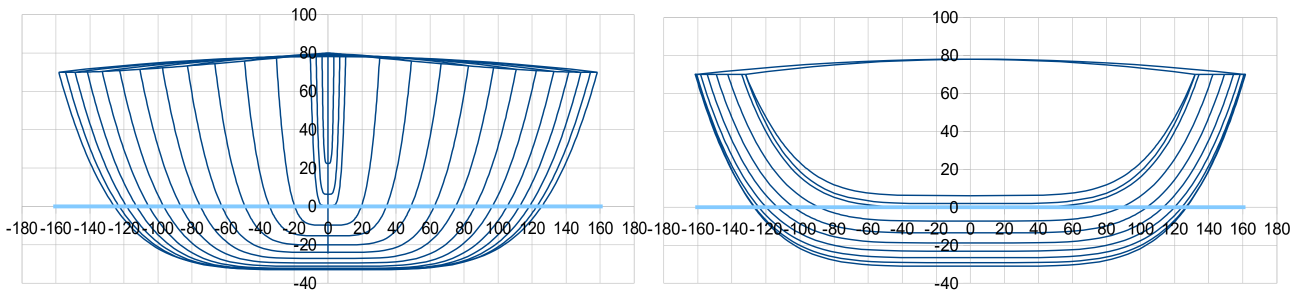


<u>Adimensional parameters for U sections</u> :

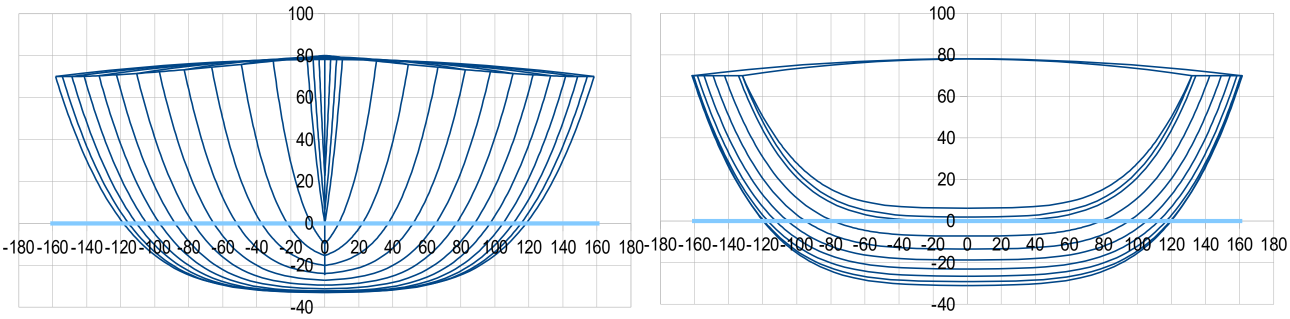
C Hu av ; C Hu ar ; Pui Hu (cells B53, B54, B55)

These parameters deal with the offset Hu / symmetry axis of the polynomial tangential horizontal point as a function of the x position of the section (formulation details in the technical appendix).
C Hu av is for the front offset and **C Hu ar** is for the rear offset, both **should be ≥ 0**. <u>The closer to 0, the more the U flatness is extended</u>.
Pui Hu is the power of the polynomial computing the evolution from C Hu ar to C Hu av.
Some examples (U sections only, without the combination with E sections) :

CHu av = 0 ; C Hu ar = 0 ; Pui Hu = 1



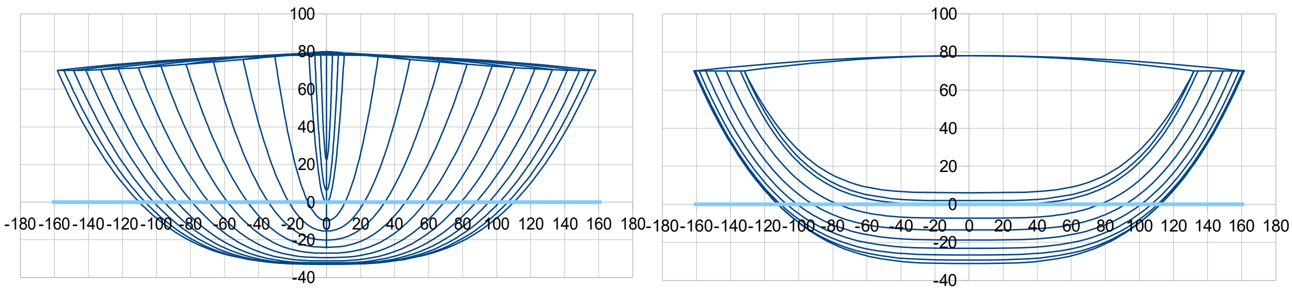
C Hu av = 0,4 ; C Hu ar = 0,16 ; Pui Hu = 1



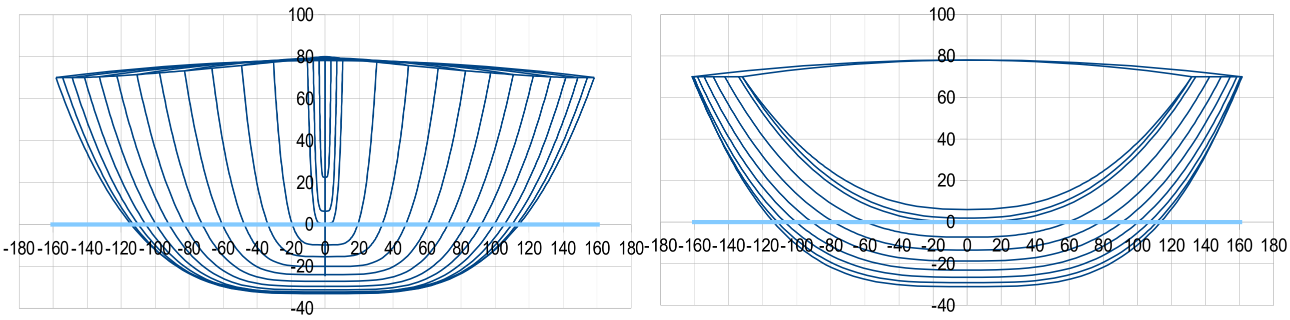
Pui U av ; Pui U ar ; Pui Pui U ; Cor Pui Pui (cells B57, B58, B59, B60)

These parameters are dealing with the power of the polynomial with position x of the section (formulation details in technical appendix). **Pui U av** for the front power; **Pui U ar** for the rear power. <u>The larger Pui U, the more the U is square shape</u>. **Pui Pui U** is the power of the polynomial computing the evolution from Pui U ar to Pui U av, and **Cor Pui Pui** is a variation with x of this power. Cor Pui Pui can be considered as a fine tuning.
Some examples (U sections only, without the combination with E sections) :

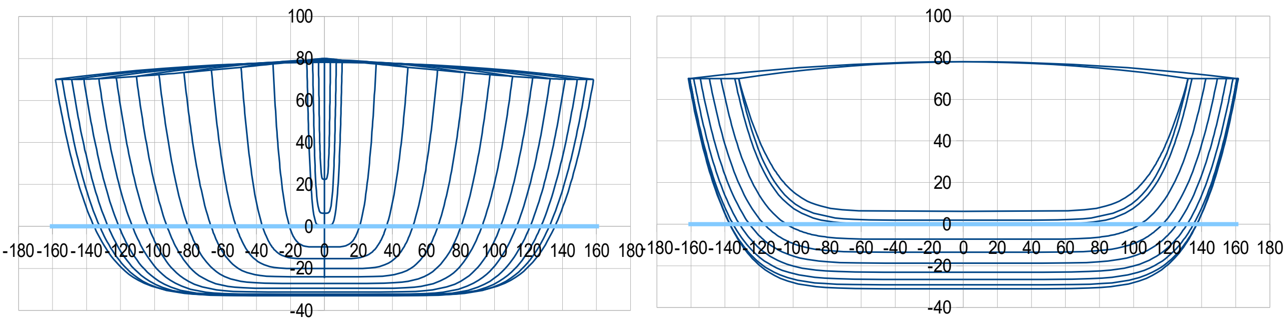
Pui U av = 2 ; Pui U ar = 4 ; Pui Pui U = 1 ; Cor Pui Pui = 0



Pui U av = 5 ; Pui U ar = 2,5 ; Pui Pui U = 1 ; Cor Pui Pui = 0



Pui V av = 5 ; **Pui V ar = 7,5 ; Pui Pui V = 4** ; Cor Pui Pui = 0



A last recommendation on input data for the hull :
Probably that the use of the polynomial parameters are not very intuitive at the beginning :

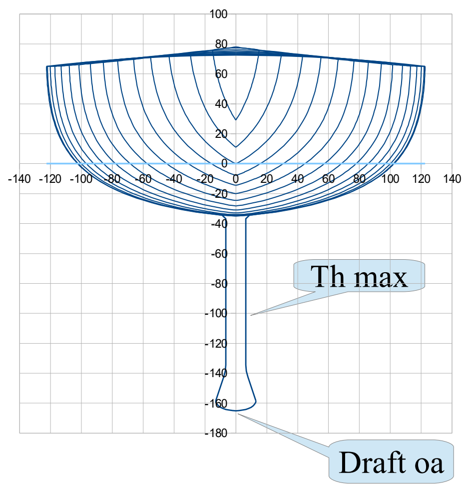
- the ones of hull of reference data are there to guide in your first steps,
- you can test the effect of each parameter, including by testing a priori very low or very high values so that to better see the effects, and this « learning by testing » process will help you to progress rapidly.

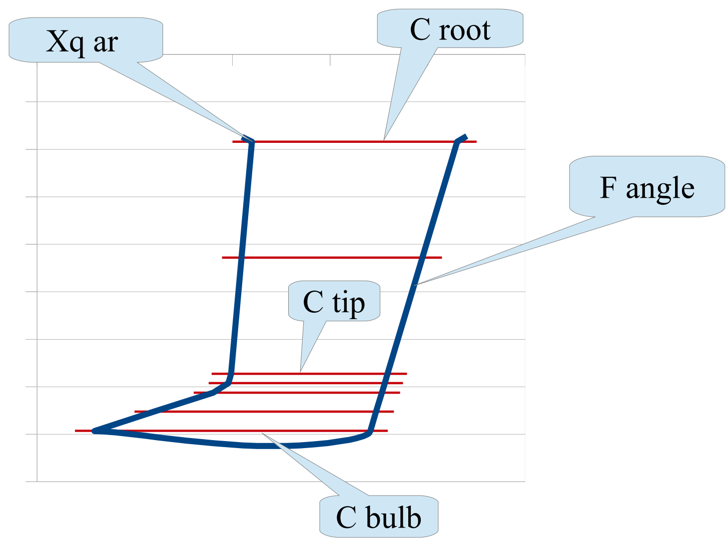
1.2 Keel data

Data to enter are in column B , cells B67 to B79 :

Xq ar (m)	**3,50**
C root (m)	**1,15**
C tip (m)	**0,90**
Th keel (cm)	**14,00**
F angle (°)	**70,00**
C bulb (m)	**1,55**
TH bulb (cm)	**28,00**
Draft oa (m)	**1,75**
naca 00xx	**0**
naca 63-0xx	**1**
naca 65-0xx	**0**
Density Keel	**7,30**
Density Bulb	**7,30**

The type of keel for this pre-design stage is a typical « inverted L » fin keel with a bulb at the tip end. Data to enter include the definition of the longitudinal profile and of the naca profiles of the various horizontal sections.





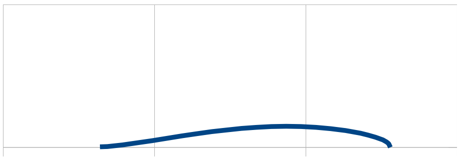
Xq ar (m) : X of the rear upper point **(cell B67)**
C root (m) : lenght of the root profile (see Nota herebelow) **(cell B68)**
C tip (m) : lenght of the tip profile before enlargement for the bulb **(cell B69)**
Th max (cm) : Maximum thickness of the profile, constant between C root and C tip. **(cell B70)**

F angle (°) : leading edge angle / horizontal, usually between 45° and 90° **(cell B71)**
C bulb (m) : lenght of the bulb profile **(cell B72)**
Th bulb (cm) : Maximum thickness of the bulb **(cell B73)**
Draft oa (m) : draft overall **(cell B74)**

Type of Naca profile : put 1 for the selected profile, 0 for the 2 others

Naca 00xx	Naca 63-0xx	Naca 65-0xx
0	**1**	0
cell B75	**B76**	**B77**

Ex : Profil Naca 63-0xx with Th max at 35% c >>>



<u>Nota :</u> Profiles are calculated and drawn with a cut-off at 97,5% c so to avoid trailing edges too tapered and unfeasible. Chords Croot, Ctip and C bulb here above are the real lenghts taking into account the cut-off, computed chord c being C/0,975.

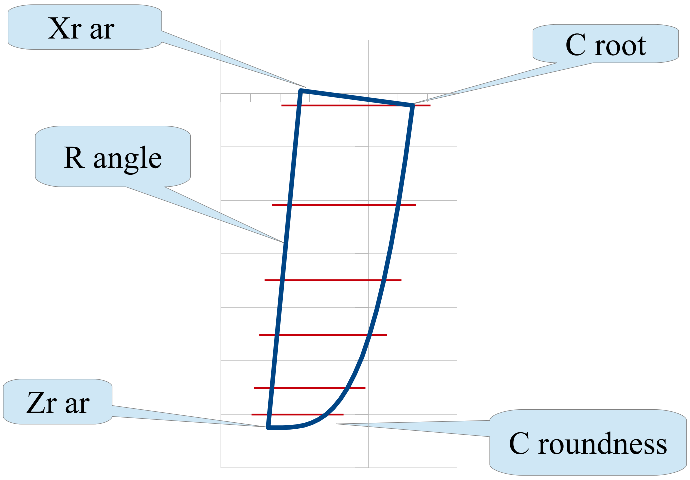
Density keel : wing part of the keel, from C root to C tip **(cell B78)**
Density bulb : Bulb part, below C tip level. **(cell B79)**
Examples : Font 7,3 ; Steel 7,85 ; Lead 11,35, ...

1.3 Rudder data

Data to enter are in column B , cells B81 to B92 :

Xr ar (m)	**-0,28**
C root (m)	**0,38**
t/c (%)	**15,00**
R angle (°)	**85,00**
L ar (m)	**1,30**
C roundness	**3,50**
naca 00xx	**0**
naca 63-0xx	**1**
naca 65-0xx	**0**
Nb of rudders	**1**
Offset y (m)	**0,00**
Angle (°)	**0,0**

As for the keel, data to enter allow the geometrical definition of the longitudinal profile of the rudder and the naca profiles used at various horizontal sections.



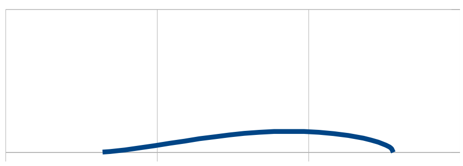
Xr ar (m) : X of the rear upper point **(cell B81)**
C root (m) : X lenght of the upper profile **(cell B82)**
t/c (%) : relative thickness of the horizontal Naca profiles, constant for the rudder. **(cell B83)**
R angle (°) : trailing edge / horizontal, usually between 75° to 85° **(cell B84)**
Zr ar (m) : Z of the rear lower point **(cell B85)**
C roudness : roundness coefficient of the mlower part of the rudder, usually 2,5 to 5,5 **(cell B86)**

Type de profil Naca : put 1 for the selected profile, 0 for the two others

Naca 00xx	Naca 63-0xx	Naca 65-0xx
0	**1**	0

cell B87 **B88** **B89**

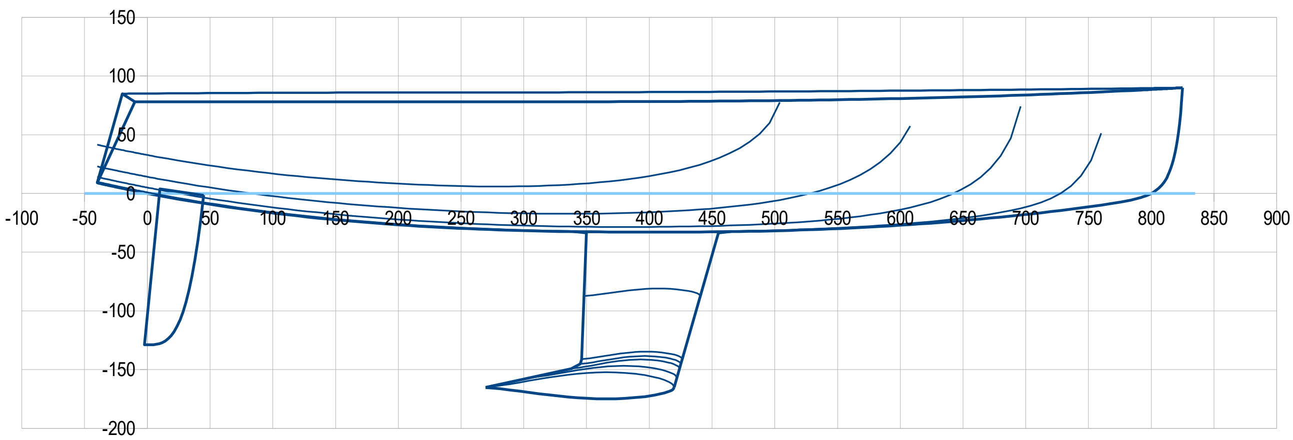
Ex : Profil Naca 63-0xx with Th max at 35% c >>>

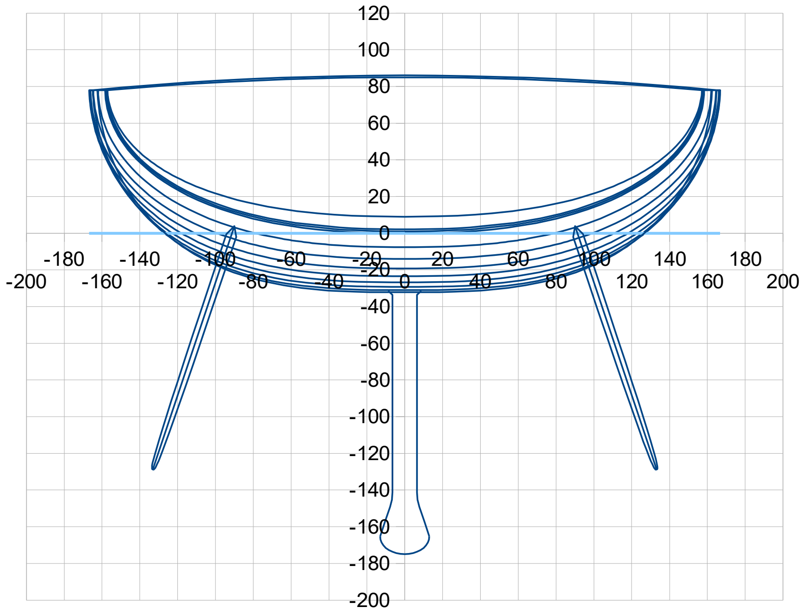


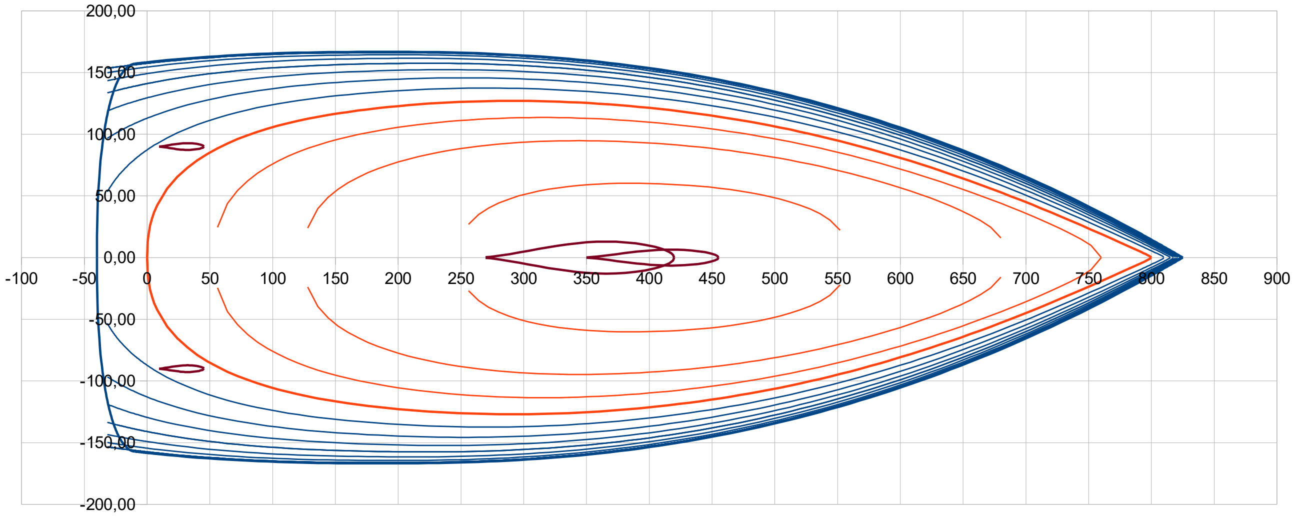
Nota : Profiles are calculated and drawn with a cut-off at 97,5% c so to avoid trailing edges too tapered and unfeasible. Computed chord c are equal to C/0,975, C being the geometrical chords.

Nb of rudders : Number of rudders, 1 ou 2 **(cell B90)**
Offset y (m) : when Nb = 2, y offset of each rudder axis / ship axis (put 0 when Nb = 1) **(cell B91)**
Angle (°) : when Nb = 2, angle / vertical of each rudder (put 0 when Nb = 1) **(cell B92)**

Example with Nb =2 rudders, Offset y = 0,9 m and angle = 18°







Storage of Gene-Hull input data : the spreadsheet includes a second sheet called **« Hulls storage »** where you can store by copy/paste the input data in column B, for your various projects or variants of a hull during the iteration process. The hulls given as examples are stored here too.

Gene-Hull sheet / output

A hull with fairing lines and hydrostatic characteristics is automatically produced as long as all data are fulfilled with consistent values. Modification of one value leads in real time to an updated version of the hull (drawings and other ouput computations).

These output are divided into several sections 2 to 7, the User should act in some of them for either change and fix the scale of the views or introduce some complementary data for specific study (the heel angle, etc …)

2. Data sum-up and results of hydrostatic and surfaces calculations

These data and results are autmatically produced, no intervention by the User.

They include parameters and ratios usually considered by naval architects to judge the consistence of the hull design, like :

- Lwl / D^(1/3)
- Bwl / B
- Displacements for 3 waterlines : H0, H0-3cm, H0+3cm,
- Xc, Zc position of the center of buoyancy
- Displacements of the keel and of the rudder, their X,Z center of buoyancy
  >>> Displacement and buoyancy position of the total hull + keel + rudder
- Cp (Prismatic coefficient) of the hull
- Sf (floatation aera) and its longitudinal center
- Sw (hull wetted surface) and ratio Sw / D^(2/3) for hull, keel and rudder.

… + the curve of the sections aeras, for 3 waterlines : H0, H0+3cm, H0-3cm

… + to contribute to the mass balance data :

- Shull (surface of the hull) , its center of gravity position X,Z
- Sdeck (surface of the deck), its center of gravity position X
- Keel weight and position of the center of gravity X,Z

...+ center of resistance LCR of the keel (according to Larsson-Eliasson method for fin keel).

…+ the recopy of the data coming from the mass spreadsheet : boat light weight and CoG location.

Example :

2. Data sum-up and results of hydrostatic and surfaces calculations

2.1 Hull

Loa (m)	10,60			Lwl (m)	8,00										
>> ft	34,78				26,25										
B (m)	2,57			at X (% Lwl)	38,0										
>> ft	8,43														
Bwl (m)	2,18			at X (% Lwl)	40,0			> Bwl / B	0,850						
>> ft	7,17									Freeboards (m) >	Aft		Midship		Fore
Tc (m)	0,36			at X (%Lwl)	50						0,67		0,65		0,78
>> ft	1,18									>> ft	2,20		2,13		2,56
		Displacement at H0 (m3)	2,42789			at Xc (m)	3,698			Xc (%Lwl)	46,23			Zc (m)	-0,125
		>> lbs	5486			w. seawater	1025		kg/m3					>> ft	-0,41
Disp at h (cm)	-3		2,07176			at Xc (m)	3,719			Xc (%Lwl)	46,49			Zc (m)	-0,114
Disp at h (cm)	3		2,80819			at Xc (m)	3,674			Xc (%Lwl)	45,92			Zc (m)	-0,136
Cp (%)	55,84														
Sf (m2)	12,28			at Xf (m)	3,552			Xf (%Lwl)	44,40					>>> Xc – Xf (%Lwl)	1,83
>> ft2	132,16			>> ft	11,65										
		Angle immersed sheer li (°)	26,9		at section C4 (40% Lwl)										
Sw (m2)	13,10			>Sw/D^(2/3)	7,25										
>> ft2	141,02														
Shull (m2)	29,10			at X (m)	3,489			Z (m)	0,063						
>> ft2	313,19			>> ft	11,45			>> ft	0,21						
Sdeck (m2)	18,76			at X (m)	3,347										
>> ft2	201,97			>> ft	10,98										

2.2 Keel

Vol. keel(m3)	0,09626			at X (m)	4,039			X (%Lwl)	50,48			Z (m)	-0,854		
Mass keel(kg)	702,71			>> ft	13,25							>> ft	-2,80		
>> lbs	1549														
Vol. Bulb(m3)	0,05412			at X (m)	3,675			X (%Lwl)	45,93			Z (m)	-1,599		
Mass bulb(kg)	395,04			>> ft	12,06							>> ft	-5,25		
>> lbs	871														
Draft oa (m)	1,75					Sw (m2)	3,67					Sxz (m2)	1,37		
>> ft	5,74					>> ft2	39,48					>> ft2	14,70		
LCR (m)	4,235			LCR (%Lwl)	52,94										
>> ft	13,89	method : keel profile extended to the waterline, LCR at 25% chord and 45% draft oa													

2.3 Rudder(s)

Number	1														
Volume (m3)	0,01352			at X (m)	-0,127			X (%Lwl)	-1,59			Z (m)	-0,541		
Sw (m2)	0,87			>> ft	-0,42							Sxz (m2)	0,42		per rudder
>> ft2	9,36											>> ft2	4,50		

2.4 Hull + Keel + Rudder(s)

		Displacement at H0 (m3)	2,59178			at Xc (m)	3,691			Xc (%Lwl)	46,13			at Zc (m)	-0,185
		(kg)	2657			>> ft	12,11							>> ft	-0,61
		>> lbs	5857												
		Ballast (kg)	1098			at Xg (m)	3,908			Xg (%Lwl)	48,85			at Zg (m)	-1,122
		>> lbs	2420			>> ft	12,82							>> ft	-3,68
		>> % Ballast	41,3												
		Sw (m2)	17,64			>Sw/D^(2/3)	9,35			Lwl/D^(1/3)	5,82				
		>> ft2	189,85							M/(Lwl/100)^3	147		tons, feet		

2.5 Data from the mass spreadsheet

Light boat:		M (kg)	2657			at Xg (m)	3,745							at Zg (m)	0,154

Hull design and mass should be adjusted so that Displacement (kg) = M (kg), and Xc (m) equal or

close to Xg (m) .

3. The 3 views 2D

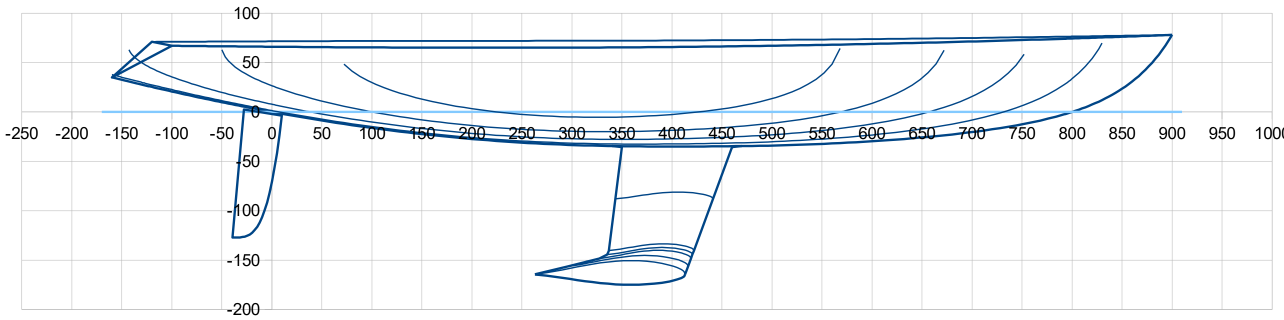
The views are automatically redrawn after every input data modification.

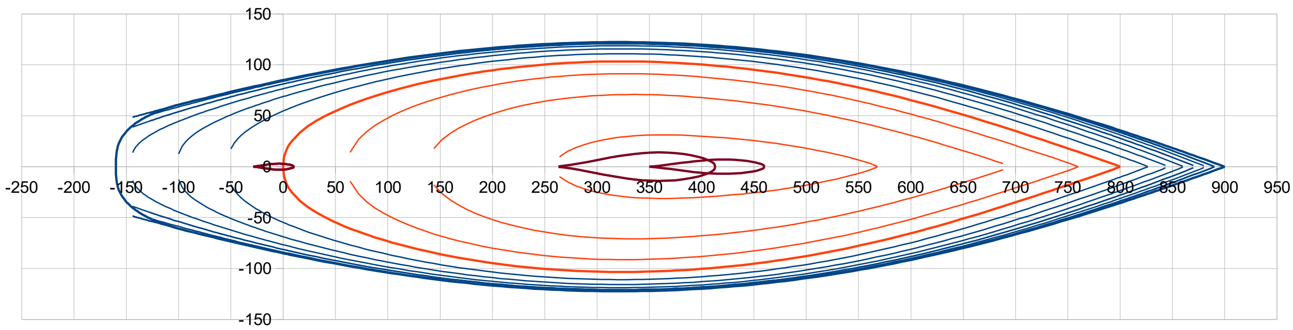
View of the front sections include sections ≥ C4 (= 40% Lwl), with a half section pitch : C4, C4,5, C5, ... In front of C10 (Front perpendicular), 2 complementary sections Cav1 and Cav2 are drawn, at 1/3 and 2/3 of the bow overlenght.
View of the rear sections includes sections ≤ C4, with a half section pitch : C4, C3,5, C3, C2,5, … Behind C0, 2 complementary sections Car1 and Car2 are drawn, Car2 at the rear end point of the sheer line and Car1 at the middle point between this rear point and C0. And the rear transom is also computed and drawn in this view (as long as it is an inverted one within the condition : X tab ar < X pont ar < X liv ar < 0).

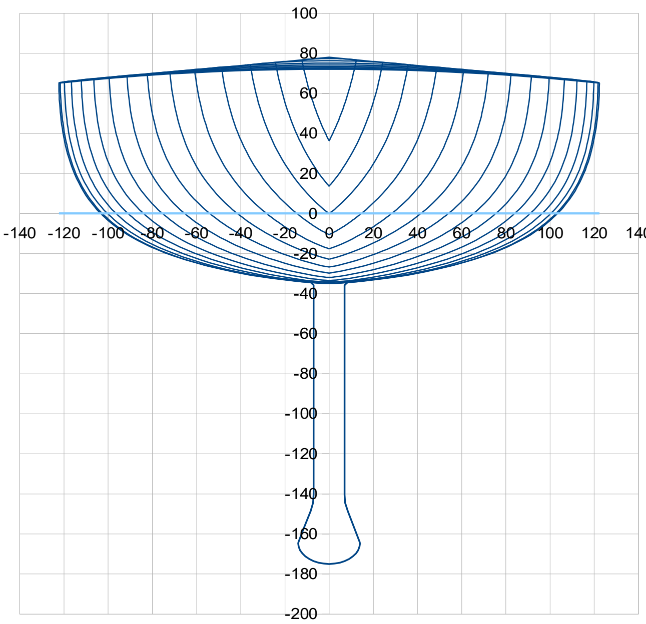
In the plan view of the bottom, waterlines in red are the wetted ones, the thick red line being the waterline H0.

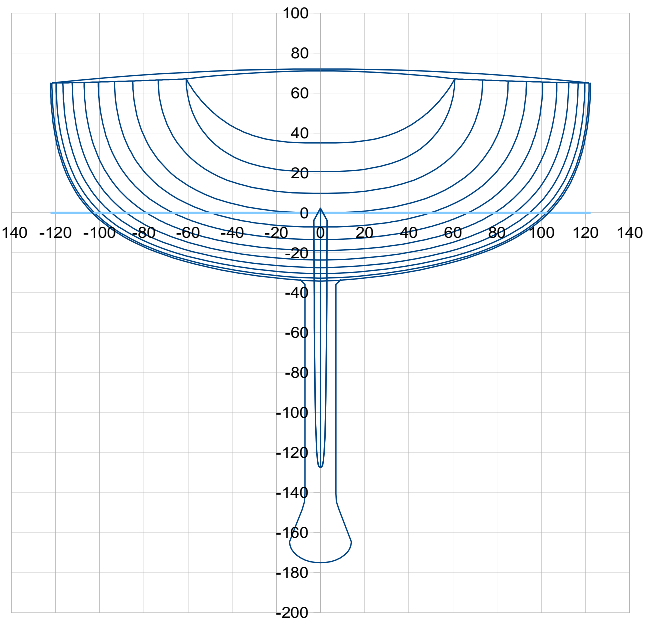
User intervention : *a*xis scales are proposed automatic, grid pitch fixed and equal for the 2 coordinates. As long as the project dimensions are fixed , it is recommended to modify (if necessary) and to fix the scale of the views for orthonormal views (i.e. square grid).

Example :









4. Curves of control

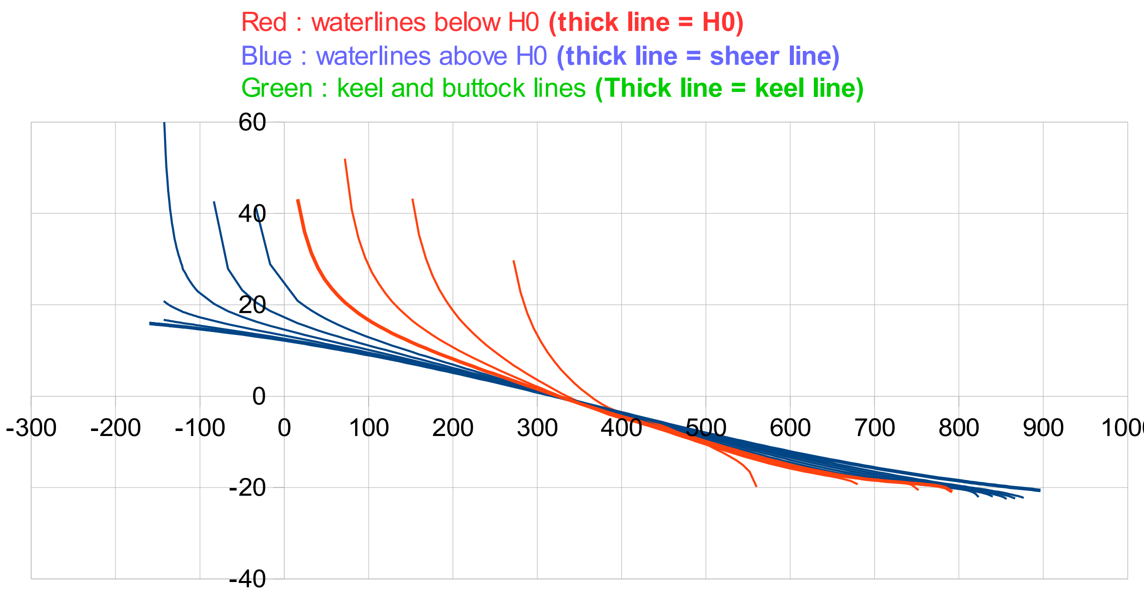
These curves are proposed to assess some complementary characteristics of the hull :

- Waterlines angles in the horizontal plan xy, with the same color code blue/red as for the bottom view.
- Curvature 1/R of :
  - Waterlines and sheer line (in the horizontal plan xy) with idem color code blue/red,
  - Keel line and Buttocks lines (vertical longitudinal cuts) in green, keel line being the thick one
- Some parameters curves, H and Pui (for sections V or U) and the combination law (for VE or UE).

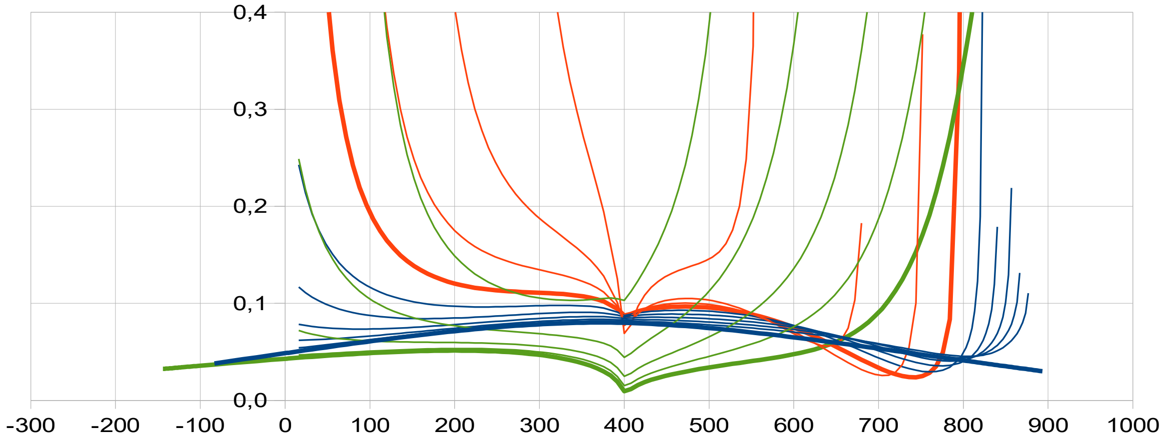
User intervention : As long as the project lenght is fixed, it is recommended to fix the scale of the X coordinates in the views.

Examples :

Waterlines angles in the horizontal plan xy



Curvature 1/R :



5. Data for transfer to a 3D modeller

These data are also automatically produced are provided to facilitate a transfer towards a 3D modeller like Multisurf or equivalent. It includes :

- x,y,z data for each section : Car1, C0, C0,5, ...etc ..., C9,5, C10, Cav1, Cav2.
- x,y,z data of the intersection curve between the rear transom and the hull,
- x,y,z data of the intersection curve between the rear transom and the deck,
- x,z data of the keel line including the bow,
- x,y,z data of the sheer line,
- x,z data of the deck central line of symmetry,
- x,z data of the longitudinal profile of the keel, data of the naca profiles in various horizontal sections
- x,z data of the longitudinal profile of the rudder, data of the naca profiles in various horizontal sections

6. Hull with heel

This section is for the computation and drawing of the hull with heel, in hydrostatic condition at constant displacement. The User should introduce 3 data + one :

- Heel angle (°) (typically 0 to 30°) **(cell B427)**
- Height (cm) : the small elevation (few cm) which help maintain constant the hull displacement ; **(cell B428)**
- Trim (°) : usually within 0° to -2° , negative value = nose down **(cell B429)**

Data to enter		**Results for iteration on height and trim**		**Data to compare with :**		**Other results for RM and obliquity**	
Heel (°)	**20,0**			**Mass (kg)**	2657,246191		
Height (cm)	**6,2482**	**Disp. (m3)**	**2,59244**	**/ Disp. (m3)**	**2,59244**	Hull Mom(m4)	0,846
Trim (°)	**-0,700**	**Xc heel (m)**	**3,745**	**/ Xg (m)**	**3,745**	Mom (kN.m)	8,50
		Other results		Xc Heel 0°	3,691	**Yg heel (m)**	**-0,053**
		Yc heel (m)	**-0,326**	Yc Heel 0°	0,000	**>> GZ (m)**	**0,273**
		Zc heel (m)	**-0,190**	Zc Heel 0°	-0,185	**RM (kN.m)**	**7,13**
		Sw heel (m2)	**16,88**	Sw Heel 0°	17,64	**Obliquity (°)**	**3,18**

–

>>> the user should iterate on the values of Height and Trim up to :

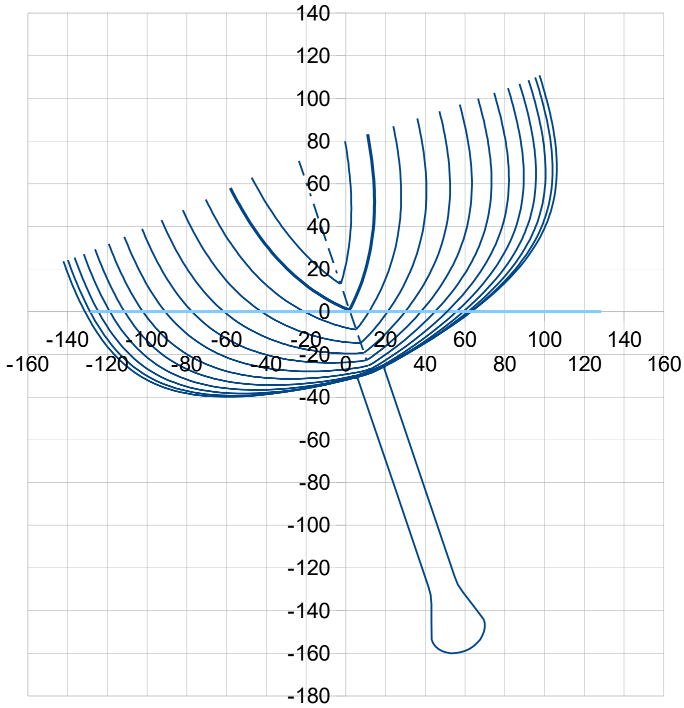
- *Displacement with heel = Displacement from the mass spreadsheet*
- *Xc heel = Xg*

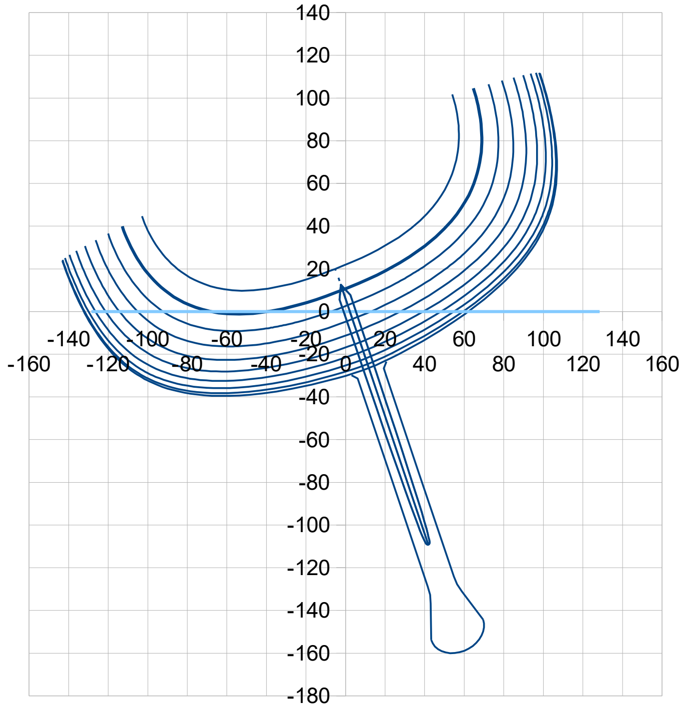
Drawings and results are then automatically produced, including :

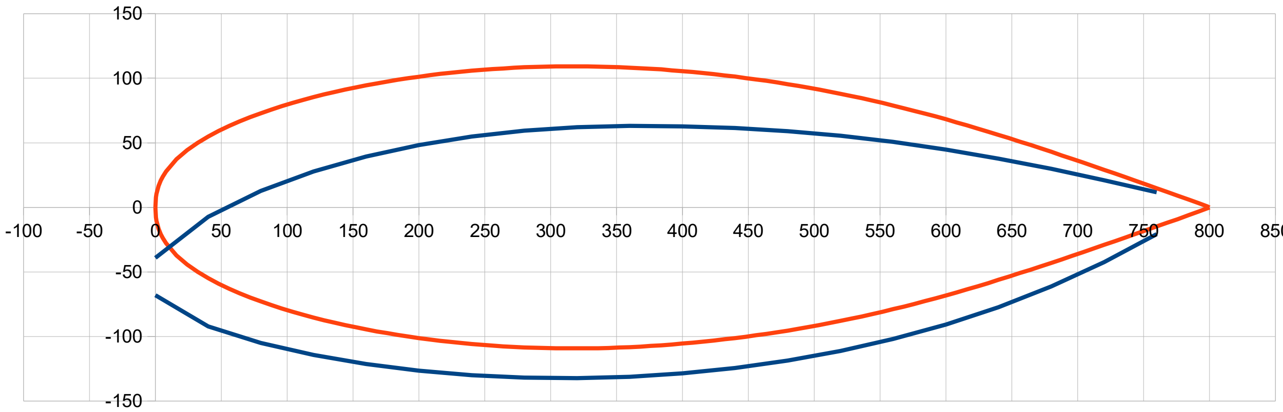
- X, Y and Z coordinates of the center of buoyancy and comparison with its initial position,
- Wetted surface Sw and comparison with the one at zero heel,
- GZ(m) and righting moment RM (kN.m)
- Average obliquity of the floatation surface (°), computed between C1 and C9 .

A plot shows the righting moment per volumes inter sections, so that to assess the hull balance with heel.

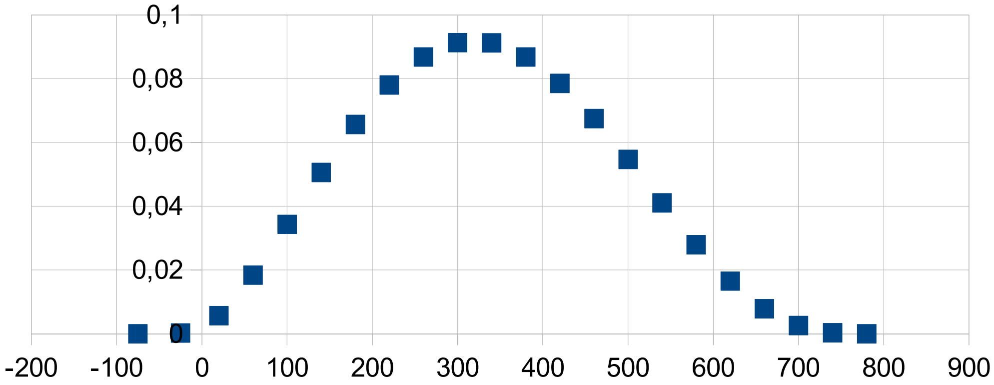
Example :







Hull Righting Moment (m4) per volumes inter sections



7. Data for hull sections drawing at scale one, inc. hull frames and deck bars

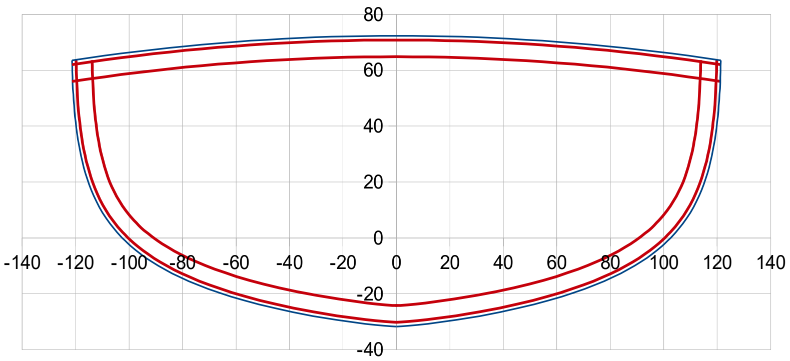
This section provides the data which can be used for a scale one drawing of any section at a given X position, inc. a hull frame or a deck bar when necessary. This section is divided in 2 sub-sections 7.1 and 7.2 for respectively sections behind or in front of C3,5.

The User should enter the X value of the section, the current thickness of the hull, the height of the hull frame, the current thickness of the deck, the height of the deck bar. **Unities : cm** .

Example :

Data to enter	**x (cm)**
>	**600,0**

Hull thickness (cm) >	**1,5**	**Frame H >**	**6**
deck thickness (cm) >	**1,5**	**Bar H >**	**6**



Sailplan input and ouput

This sheet can provide an early stage definition of the sailplan, with 2 main results about the sail

surface St (Main + Fore triangles) and the so-called « Lead ». Also computed are ratios usually considered by naval architects.

Data to enter		>> *in feet*
Xmast (m)	**4,60**	*15,09*
Zboom(m)	**1,62**	*5,31*
I (m)	**10,80**	*35,43*
J (m)	**3,50**	*11,48*
P (m)	**10,90**	*35,76*
E (m)	**3,50**	*11,48*

Results for the Sailplan (i.e. Fore + Main triangles)				
Geometrical center				
Xv (m) 4,594	Zv (m)	4,830		
Surface triangles St (m2)	**37,98**	*408,76*	*sqft*	
>> St / Sw	2,15			
>> St / D^(2/3)	20,13			
>> Skeel / St (%)	3,60			
>> Srudder / St (%)	1,10			
Lead (Xv – CLR) (% Lwl)	**4,5**			

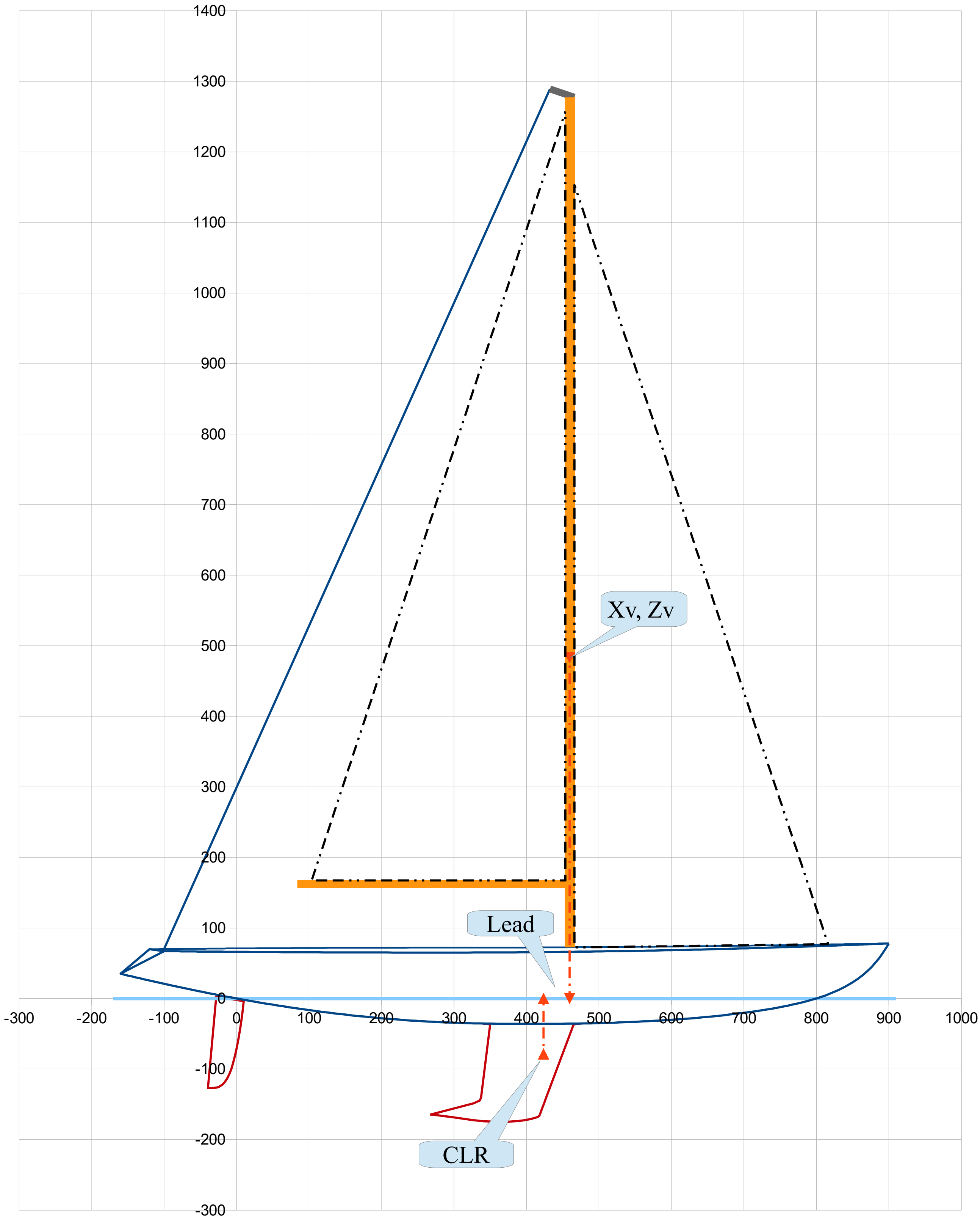
The 6 input data in column B, cells B3 to B8. The other needed data come from the gene-hull sheet.

Xmast (m) : is the X position of the mast **(cell B3)**
Zboom (m) : is the Z position of the boom **(cell B4)**
I (m) , J (m) : are the fore triangle height and base **(cells B5, B6)**
P (m), E (m) : are the main triangle height and base **(cells B7, B8)**

The output includes data and ratios in relation with the sailplan triangles surface and position, and a 2D drawing :

- The geometrical center of the sailplan triangles : Xv, Zv
- The surface of the triangles St
- ratio St / Sw , Sw being the wetted surface
- ratio St / D^(2/3), D being the displacement
- ratio Skeel / St , Skeel being the xz surface of the keel wing
- ratio Srudder / St, Srudder being the xz surface of the rudder (of one rudder in case of twin rudders)
- Lead Xv – CLR, CLR being the Center of Lateral Resistance by this method : keel profile extended to the waterline, CLR at 25% chord and 45% draft oa

, all the needed data for these ratios automatically coming from the Gene-Hull sheet.


1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
-200
-300
-300
-200
-100
0
100
200
300
400
500
600
700
800
900
1000
Xv, Zv
Lead
CLR

Mass spreadsheet input and output

This mass speadsheet can provide an early stage estimation of the light weight mass and CoG position, in order to help adjust accordingly the hull design concerning its displacement and CoD position.

Mass and Xg, Zg position – early stage estimation Data from Gene-Hull sheet are in blue **Data to enter are in black** (inc. default value to initiate)	Input data L or S or V m or m2 or m3	mass unit or % Disp.	Results Mass (kg)	Xg (m)	M Xg	Zg (m)	M Zg
Hull (skin, structure, keel interface) *, with S, Xs and Zs from Gene-Hull sheet*	29,10	**18,00** (kg/m2)	523,74	3,49	1827,17	0,06	32,97
Deck – roof – cockpit (skin and structure) *, with S, Xs and Zs from Gene-Hull sheet*	18,76	**14,00** (kg/m2)	262,69	3,35	879,30	0,72	189,14
Rig, sails and deck fittings		**15,00** (% Disp.)	398,49	**4,00**	1593,95	**3,50**	1394,70
Cabin accomodation and motor		**13,00** (% Disp.)	345,35	**3,95**	1364,15	**0,12**	41,44
Keel			1097,76	3,91	4289,69	-1,12	-1232,01
Rudder		**1,10** (% Disp.)	29,22	-0,13	-3,72	-0,54	-15,80
		Results : Light weight boat >>>	**2657,25**	**3,74**	9950,53	**0,15**	410,44

The input data to enter by the user and based on his experience, are in black bold police, including :

- **(cell C5)** average mass / m2 for Hull (skin, structure, reinforcements) , based on the hull surface data in cell B5 and coming from the Gene-Hull sheet
- **(cell C7)** average mass / m2 for Deck (deck, roof cockpit, reinforcements) , based on the hull surface data in cell B5 and coming from the Gene-Hull sheet
- **(cell C9)** average mass / % Disp. for Rig, sails and deck fittings, **(cell E9)** and **(cell G9)** for the X and Z position of this mass
- **(cell C11)** average mass / % Disp. for cabin accomodation and motor, **(cell E11)** and **(cell G11)** for the X and Z position of this mass
- **(cell C15)** average mass / % Disp. for the rudder system

The output data, light weight boat mass and position Xg, Zg are reported in the Gene-Hull sheet, and also used in the Hull with heel study.

Annex : main formulations involved in Gene Hull

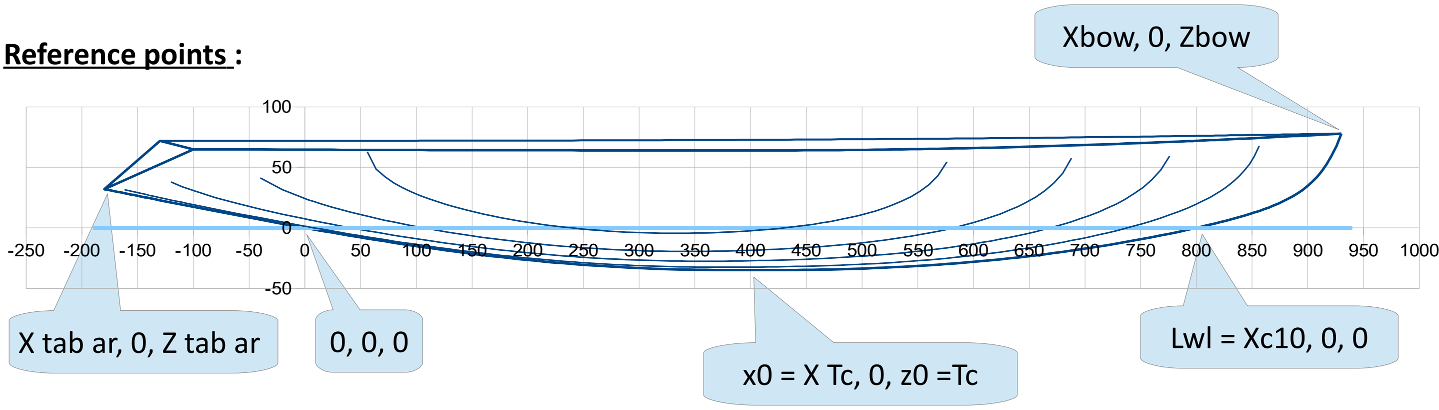
As a complement to the User Guide, this annex proposes the main formulations involved in Gene-Hull. for the geometrical definition of the keel line, of the sheer line and of the sections.

Coordinates system :

x = 0 at section C0 (= rear point of the waterline), x positive towards front
y = 0 in the symmétrical longitudinal plan, y positive towards starboard,
z = 0 waterline surface, z positive towards up

1. The keel line in the vertical plan of symmetry xz

Reference points :



The keel line is defined by 2 polynomes for respectively the fore part (when x > x0) and the rear part (when x < x0). Both polynomes are of the type :

$$z = z_0 + a\,(x - x_0)\text{^}[b + c\,(X-X0)\text{^}n]$$

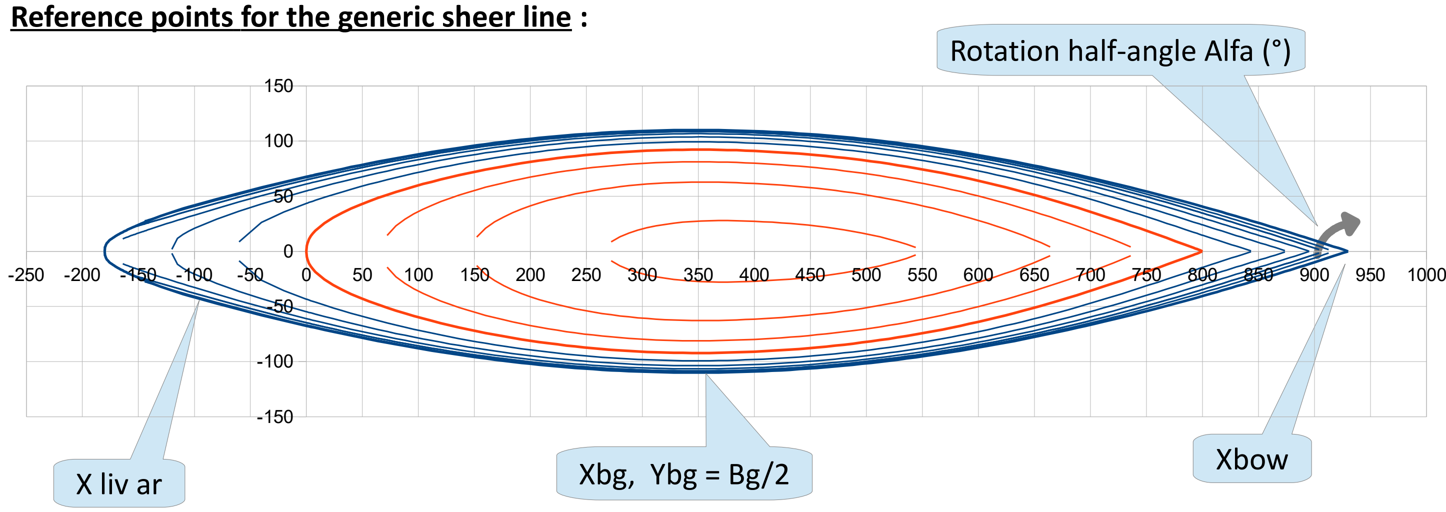
, where a, b, c are defined to comply with the reference points showed here above and n is an adimensional parameter :

- n = Cet, an additional input for the fore polynome, contibuting to shape the bow, Cet can vary from 0,1 to 100
- n = 1, for the rear polynome.

2. The sheer line, in its horizontal projection xy

The sheer line is computed through a 2 steps method : at first the sheer line of a generic hull, then the real sheer line by « opening » the previous one of an half angle alfa with the bow end as the center of rotation. Exactly, only the y values issued from the rotation are taken into account, the x values are kept unchanged.

Reference points for the generic sheer line :



The generic sheer line is defined by a polynome of this type :

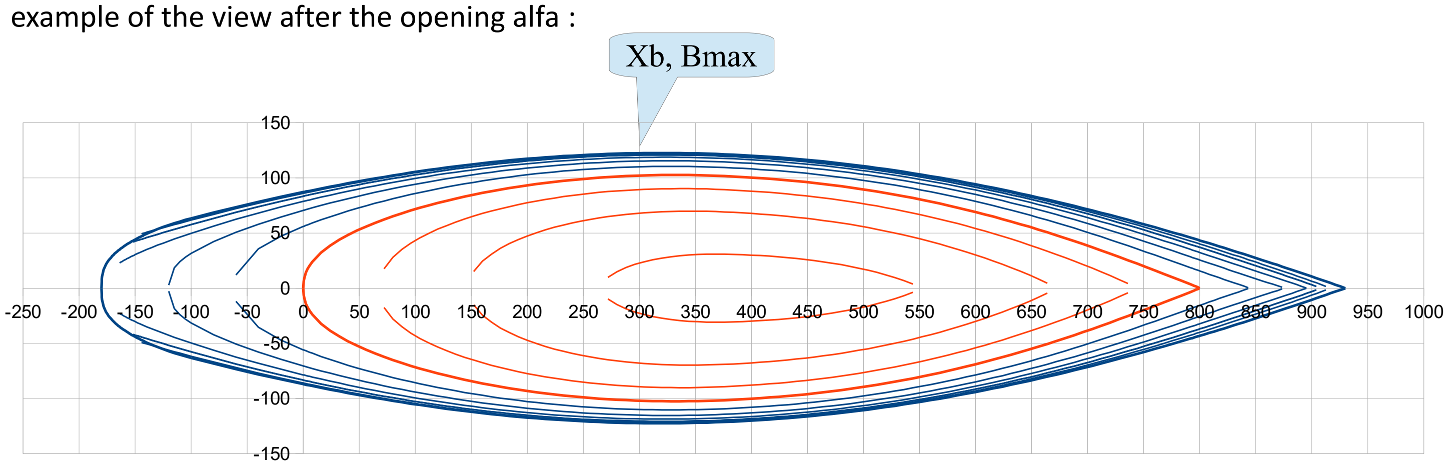
$$Y_g = B_g/2 - a\ |X_{bg} - X|^{(b + c\,|X_{bg} - X|^n)}$$

, where a, b, c are computed to comply with the reference points showed here above and n is an adimensional parameter.

Then the real sheer line is computed through :

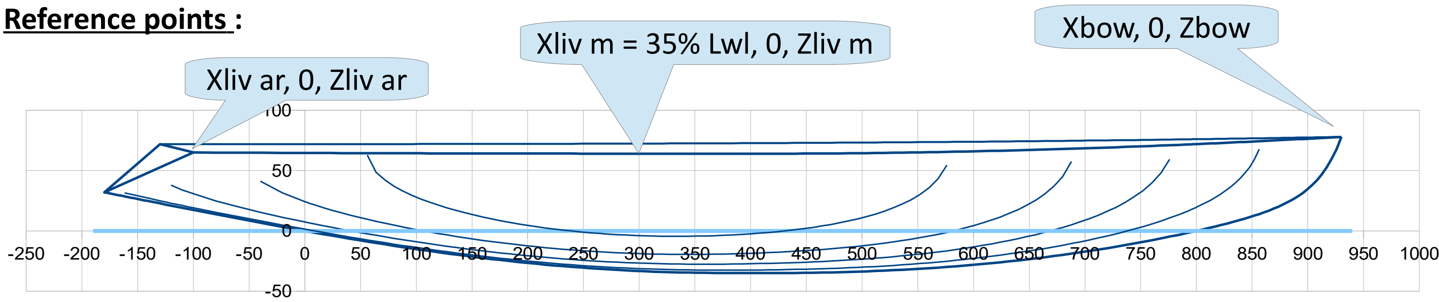
$$Y = Y_g + (X_{bow} - X)\sin(alfa) + Y_g\,(1-\cos(alfa))$$

After this reformulation of Y, the maximum beam Bmax and its postion Xb can be computed. An example of the view after the opening alfa :



3. Sheer line / in its vertical projection xz

Reference points :



The keel line is defined by 2 polynomes for respectively the fore part (when x > 35% Lwl) and the rear part (when x < 35% Lwl). Both polynomes are of the type :

$$\text{Fore :}\quad Z = Z_{liv\,m} + (Z_{bow} - Z_{liv\,m}) / (X_{bow} - X_{liv\,m})^{n} * (X - X_{liv\,m})^{n}$$

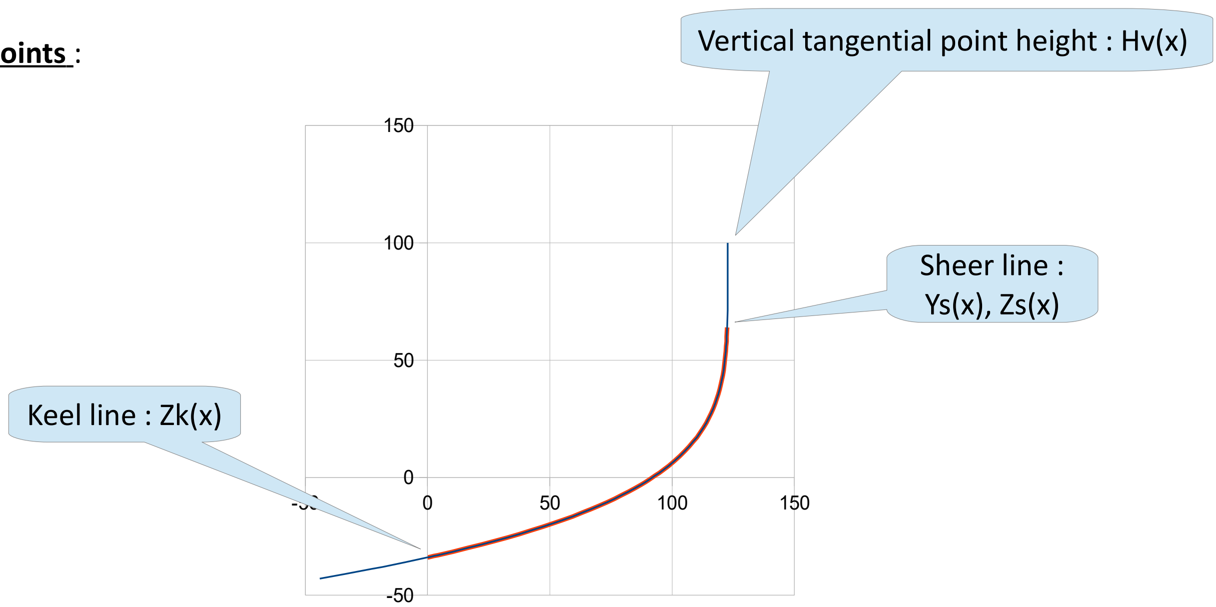
$$\text{Aft :}\quad Z = Z_{liv\,m} + (Z_{liv\,ar} - Z_{liv\,m}) / (X_{liv\,m} - X_{liv\,ar})^{n} * (X_{liv\,m} - X)^{n}$$

4. Sections

3 types of elemntary sections are defined, « V » shape, « U » shape and « E » shape, and then combination of either V and E shapes, or U and E shapes, is operated to define the real sections.

4.1 « V » shape sections

Reference points :



The formulation is of the type :

$$Y_V(x,z) = A(x) - (H_V(x) - z)^{Puiv(x)} / B(x)$$

, with :

$H_v(x) = H_{v\,m} + (H_{v\,ar} - H_{v\,m})*[|X - X_5| / |X_{tab\,ar} - X_5|]^{PuiHv}$ for $x < x_5$

$H_v(x) = H_{v\,m} + (H_{v\,av} - H_{v\,m})*[|X - X_5| / |X_{tab\,av} - X_5|]^{PuiHv}$ for $x > x_5$

$P_{uiv}(x) = P_{uiv\,ar} + (P_{uiv\,av} - P_{uiv\,ar})*[(X - X_{tab\,ar})/(X_{bow} - X_{tab\,ar})]^{[PuiPuiv - CorPuiPuiv*(X - Xtab\,ar)/(Xbow - Xtab\,ar)]}$

$B(x) = [(H_v(x) - Z_k(x))^{Puiv(x)} - (H_v(x) - Z_s(x))^{Puiv(x)}]/Y_s(x)$

$A(x) = [(H_v(x) - Z_k(x))^{Puiv(x)}]/B(x)$

, where the input data are the adimensional parameters :

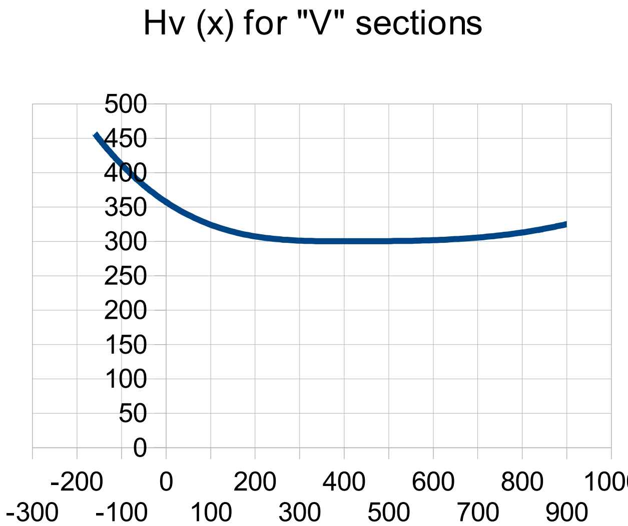
C Hv av
C Hv m
C Hv ar
Pui Hv
Pui V av
Pui V ar
Pui Pui V
Cor Pui Pui V

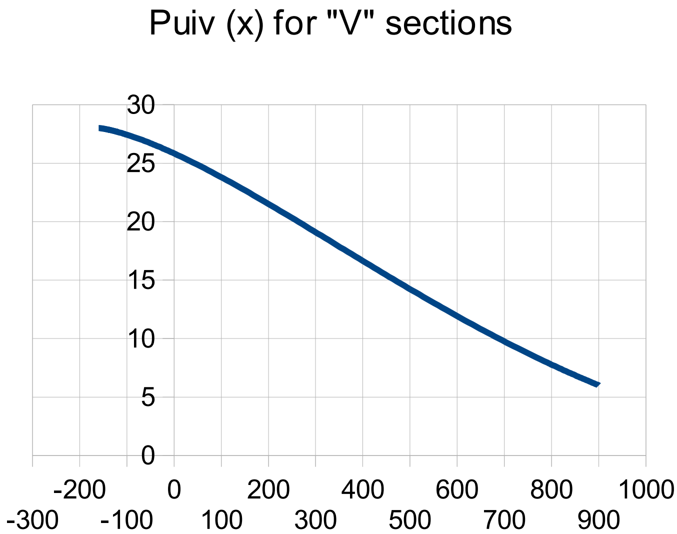
, and :

X_5 = 50% Lwl

Hv ar = C Hv ar * Zliv ar ; Hv m = C Hv m * Z liv m ; Hv av = C Hv av * Zbow

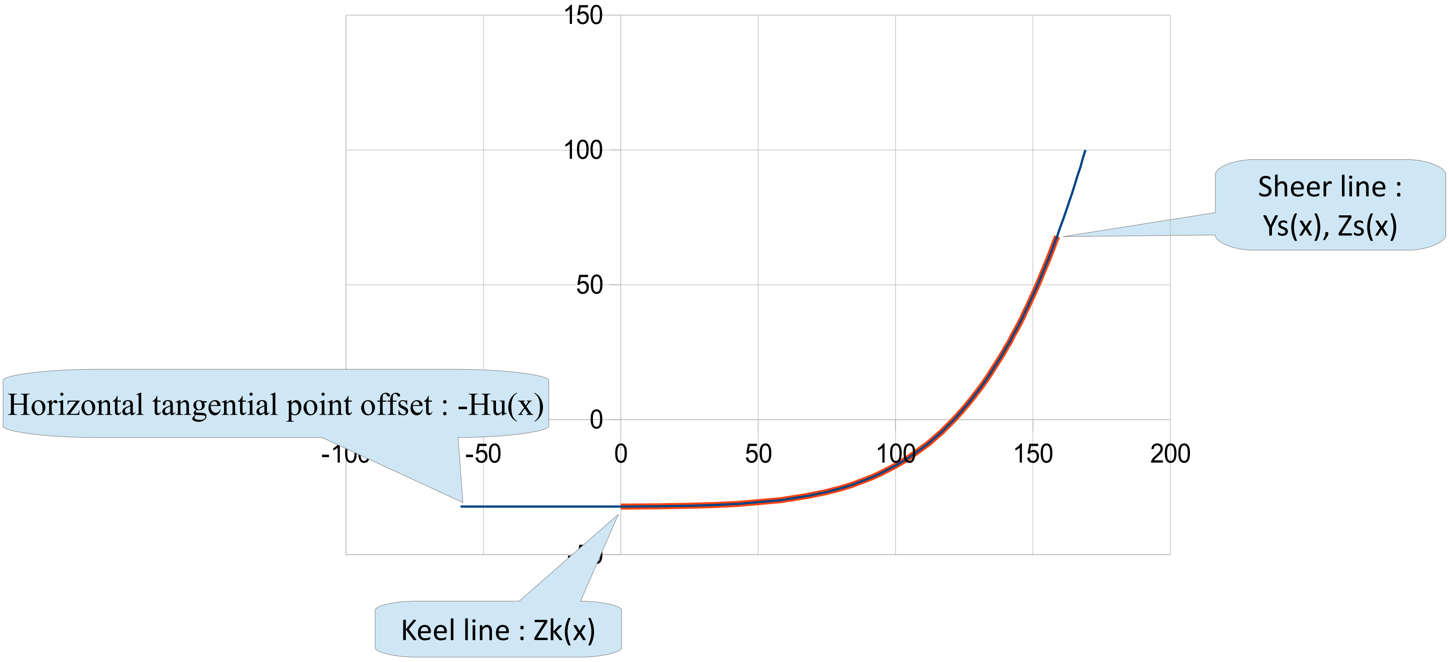
Examples of Hv(x) and Puiv(x) functions :





4.2 « U » shape sections

Reference points :



The formulation is of the type :

$$Y_u(x,z) = -H_u(x) + [(z - T(x))/U(x)]^{(1/Puiu(x))}$$

, with :

$$H_u(x) = H_{u\,ar} + (H_{u\,av} - H_{u\,ar})*[(X - X_{tab\,ar})/(X_{bow} - X_{tab\,ar})]^{PuiHu}$$

$$Puiu(x) = Puiu_{ar} + (Puiu_{av} - Puiu_{ar})*((X - X_{tab\,ar})/(X_{bow} - X_{tab\,ar}))^{[PuiPuiu - CorPuiPuiu*(x - Xtab\,ar)/(Xbow - Xtab\,ar)]}$$

$$U(x) = (Z_s(x) - Z_k(x))/((Y_s(x)+H_u(x))^{Puiu(x)} - H_u(x)^{Puiu(x)})$$

$$T(x) = Z_k(x) - U(x)*H_u(x)^{Puiu(x)}$$

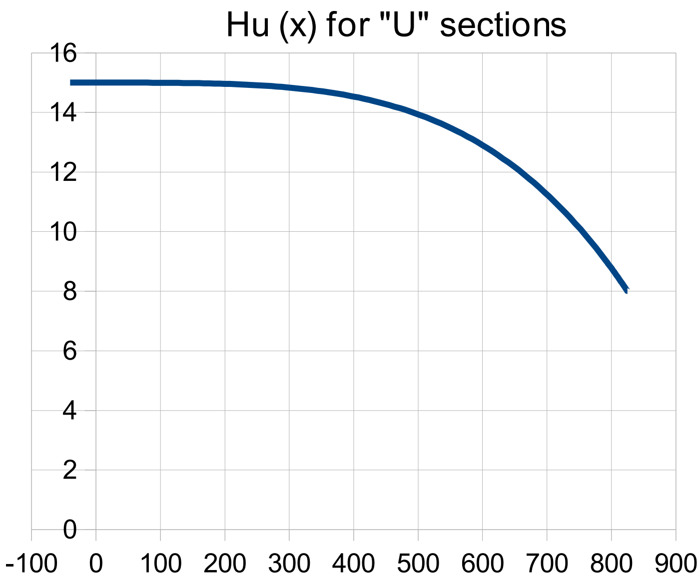
, where the input data are the adimensional parameters :

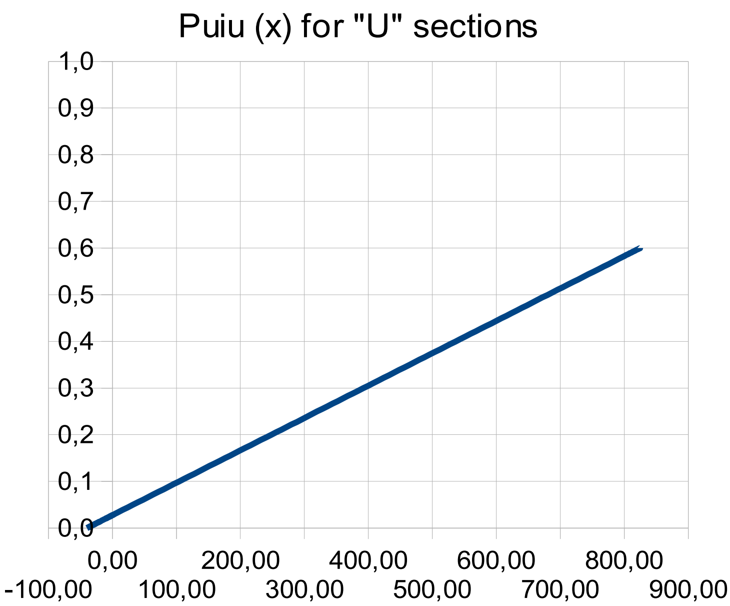
C Hu av
C Hu ar
Pui Hu

Pui U av
Pui U ar
Pui Pui U
Cor Pui Pui U

, and Hu av = C Hu av * (Bmax /2) ; Hu ar = C Hu ar * (Bmax/2)

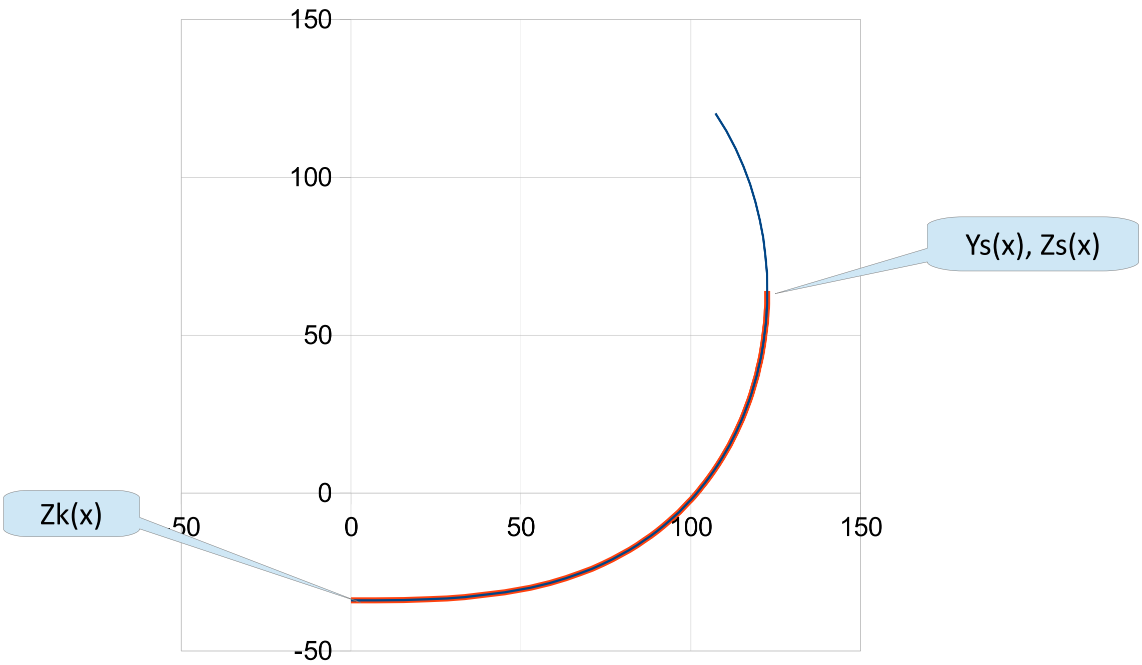
Examples of Hu (x) and Puiu (x) functions :





4.3 « E » shape sections

Reference points :



The formulation is of the type :

$$Y_E(x,z) = Y_S(x) - [1-((Z_S(x) - z)/(Z_S(x) - Z_K(s))^{\wedge}2]^{\wedge}(1/PuiE)$$

, where the input adimensional parameter is $\mathbf{P_{uiE}}$

4.4 Combination of shapes

Two combinations are proposed :

- VE sections
- UE sections

The combination law is the same in both cases :

VE sections : $Y_{VE}(x,z) = Y_V(x,z)^{\wedge mix(x)} * Y_E(x,z)^{\wedge(1-mix(x))}$

UE sections : $Y_{UE}(x,z) = Y_U(x,z)^{\wedge mix(x)} * Y_E(x,z)^{\wedge(1-mix(x))}$

, with :

$$mix(x) = mix_{av} + (mix_{ar} - mix_{av}) * [(X_{bow} - X)/(X_{bow} - X_{tab\ ar})]^\wedge P_{uimix}$$

, where the input data are the adimensional parameters :

mix VE av
mix VE ar
Pui mix VE

Examples of mix(x) :

mix (x) law combination for the sections